ISSN 2571-1075.
Volume 01,issue 01,2018

INTERNATIONAL JOURNAL of BIM&ENGINEERING SCIENCE

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International Journal of BIM and Engineering Science

Available online at: http://bimarabia.com/IJBES/

December- 2018; Volume: 1 Issue: 1 **ISSN 2571-1075**

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About the journal

International Journal of BIM and Engineering Science (IJBES) is an international, peer reviewed journal, publishing high-quality, original research.

Aims & Scope

IJBES aims to provide researchers and experts with up-to-date research in BIM and its relation with Engineering Science, and to facilitate the global exchange and review of research, ideas and expertise among individuals in the scientific community.

IJBES publishes original peer-reviewed research papers, case studies, technical notes, book reviews, features, discussions and other contemporary articles that advance research and practice in **Building Information Modeling** in architectural, engineering, and construction management, advance integrated design and construction practices, project lifecycle management, and sustainable construction. The journal's scope covers all aspects of **architectural design, design management, construction/project management, engineering management of major infrastructure projects, and the operation and management of constructed facilities**. IJBES also addresses the **technological, process, economic/business, environmental/sustainability, political, and social/human developments that influence the construction project delivery process**.

IJBES strives to establish strong theoretical and empirical debates in the above areas of engineering, architecture, and construction research. Papers should be heavily integrated with the existing and current body of knowledge within the field and develop explicit and novel contributions. Acknowledging the global character of the field, we welcome papers on regional studies but encourage authors to position the work within the broader international context by reviewing and comparing findings from their regional study with studies conducted in other regions or countries whenever possible

International Journal of BIM and Engineering Science

Available online at: http://bimarabia.com/IJBES/

December- 2018; Volume: 1 Issue: 1 **ISSN 2571-1075**

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International Journal of BIM and Engineering Science

Available online at: http://bimarabia.com/IJBES/

December- 2018; Volume: 1 Issue: 1 **ISSN 2571-1075**

Issue Introduction

It's a pleasure to present the first issue for International Journal of BIM and Engineering Science (IJBES). IJBES is one of the scientific journals that BIMarabia s.r.o publish. BIMarabia is a publisher of peer-reviewed, open access academic journals and books. BIMarabia aims to provide researchers, professors and students with up-to-date research in BIM and its relation with Engineering Science, and to facilitate the global exchange and review of research, ideas and expertise among individuals in the scientific community. Established in 2015, BIMarabia has attracted over 20000 scientists worldwide. All content published by BIMarabia offers unrestricted access, and distribution, in any medium; provided the original work is correctly cited. We ensure the highest standards of peer-review for all manuscripts submitted for publication, thanks to the highly qualified scientists who are members of our journal's Editorial Board. BIMarabia delivers support throughout the complete publishing process in an efficient and effective manner.

Architectural, Engineering and Construction (AEC) industry has a giant influence in different nations' economic growth, however, it suffers from myriad problems. AEC industry projects faced issues such as being behind schedule, over budget, inferior quality, low productivity, without sustainability and more. The key players wandered about technology, methodology, or tools that can mitigate or solve these problems. Several researchers and professionals prove that Building Information Modelling (BIM) could help in solving the AEC industry problems. Despite there is no consensus about the definition of BIM; researchers and professionals recognize and appreciate the benefits of using BIM.

Therefore, IJBES concerns about BIM and the related and relevant engineering Science. The first volume, first issue, contains three articles. The first one deals with an exploratory study of BIM maturity in the construction industry. Whereas the second one discusses BIM performance improvement framework for Syrian AEC companies. Finally, the third article discusses the obstacles and requirements for BIM Implementation in Syria.

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International Journal of BIM and Engineering Science

Available online at: http://bimarabia.com/IJBES/

December- 2018; Volume: 1 Issue: 1 **ISSN 2571-1075**

An Exploratory Study of Building Information Modelling Maturity in the Construction Industry

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Abstract:

Despite the benefits of Building Information Modelling (BIM), the adoption level of BIM remains much lower than expected. Construction companies should appraise the existing condition in the BIM implementation to ascertain the applicable progress avenues that fit the user's traits. To achieve this aim, the objectives of this paper are i) to identify the trends of BIM maturity studies ii) to conceptualise what is BIM maturity; iii) to identify the existing models of BIM maturity iv) to identify the indicators for measuring BIM maturity in the company, the project and the industry. A systematic review was conducted on BIM maturity articles, published in the Scopus database from 2008 to April 2018. The results reveal that most BIM maturity studies are dominated by authors from the United Kingdom and the United States, but the top three authors highly-cited were from Australia, Canada and the United Kingdom. The results highlight four aspects in the conceptualisation of BIM maturity: quality of use, the extent of use, the context of use and stages of the processes. The four most frequently quoted BIM maturity models are the National BIM Standard Capability Maturity Model, BIM maturity, BIM proficiency matrix and BIM implementation models. The results revealed seven major indicators for assessing BIM maturity namely information, people, policy, process, technology, organisation and BIM output. The findings advance the practitioners' understanding of important indicators that must be considered to initiate or increase the BIM maturity levels in their respective companies or projects.

Keywords: BIM maturity; BIM maturity models; indicators; construction industry

1. Introduction:

With increasing demand from various stakeholders for better performance, managing construction projects has become more complex and challenging (Dubois and Gadde, 2002; Blayse and Manley, 2004; Almeida and Soares, 2014). Building Information Modelling (BIM) is considered as an innovative way of addressing the many problems that arise in the design, construction and maintenance of buildings. BIM refers to "a set of interacting policies, processes and technologies generating a methodology to manage the essential building design and project data in digital format throughout the building's life cycle" (Succar, 2009, p. 357). BIM is considered as a part of Industry 4.0 (Oesterreich and Teuteberg, 2016). The visionary idea of Industry 4.0 is to create a value-added

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chain that enables integration between products, their environment and business partners, and consequently, to increase productivity and improve the performance of the enterprise through digitization and automation (Brettel et al., 2014). BIM can be utilised in all phases across the project life cycle: the owner can use BIM to appreciate the needs of the project, designers can use BIM to examine, design and advance the project, the contractor can use BIM in managing the construction processes, and the facility manager can use BIM in the operations and maintenance phases (Grilo and Jardim-Goncalves, 2010).

Recently, there was a growing interest within the industry players to use BIM due to its advantages in increasing project performance (Ghaffarianhoseini et al., 2017; Brettel et al., 2014). Despite the benefits of using BIM in the construction industry at all stages of the project life cycle, the adoption level of BIM remains much lower than expected in most developing countries (see Addy et al, 2018; CIDB, 2017; Ramanayaka and Venkatachalam, 2015). Construction companies should appraise the existing condition in the BIM implementation to ascertain the applicable progress avenues that fit the user's traits (Won et al., 2013; Liao and Teo, 2018).

The above scenario raises several questions in the study – What is the trend in BIM maturity studies? What is BIM maturity? What are the BIM maturity models currently available? What are the indicators used for assessing BIM maturity? At the time of writing this article, scholars have not yet agreed on the indicators for assessing BIM maturity. To address these questions, a systematic review is conducted using bibliometric analysis with the objective of identifying the trends of BIM maturity studies, defining the meaning of BIM maturity, identifying BIM maturity models and indicators for assessing BIM maturity. Practically, the results are significant for BIM personnel, companies and project teams to determine their current BIM performance and benchmark against the target of the industry for prioritisation and improvement to progress to the next level. Theoretically, the identified indicators can be used as a basis for future studies on BIM maturity. Next, the methodology of the paper is presented.

2. The methodology of a Systematic Review:

A systematic review involving a four-stage process was conducted. Stage 1: searching for titles, abstracts and keywords using the words 'BIM maturity' or 'building information modelling maturity'. The search involved all the articles published in the Scopus database. Using the document search 'BIM and maturity', 'building information modelling and maturity' and 'information modelling and maturity', article titles, abstracts and keywords resulted in 97 articles. Stage 2: selecting relevant articles that include only articles published in English journals or conference proceedings, as well as articles related to the architecture, engineering and construction sectors. This exercise resulted in 75 articles. Stage 3: Profiling of the selected articles. The objective is to identify the general trend in BIM maturity studies, such as the volume of research and the contributors in terms of authors, sources and countries. Stage 4: using content analysis to categorise and conceptualise BIM maturity, identify BIM maturity models and indicators for BIM maturity.

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3. Results and discussions:

3.1 *Profiling of BIM maturity studies*

The profiling of the 75 articles on BIM maturity aimed to identify the general trend in BIM maturity studies. analyses both the quantity and quality of BIM maturity articles. In terms of quantity, the number of articles published from 2008 to 2018, the source title, the most productive authors and the country of origin of the articles were analysed. The analysis revealed that the article on BIM maturity was first published in 2008, indicating that the research topic is relatively new. However, the number of articles on BIM maturity began to increase exponentially after 2011, where 92% of BIM maturity was published between 2012 and 2018, indicating that BIM maturity model is still prevalent among researchers. Figure 1 depicts the number of BIM maturity articles that were published in the Scopus database from 2008 to 2018.

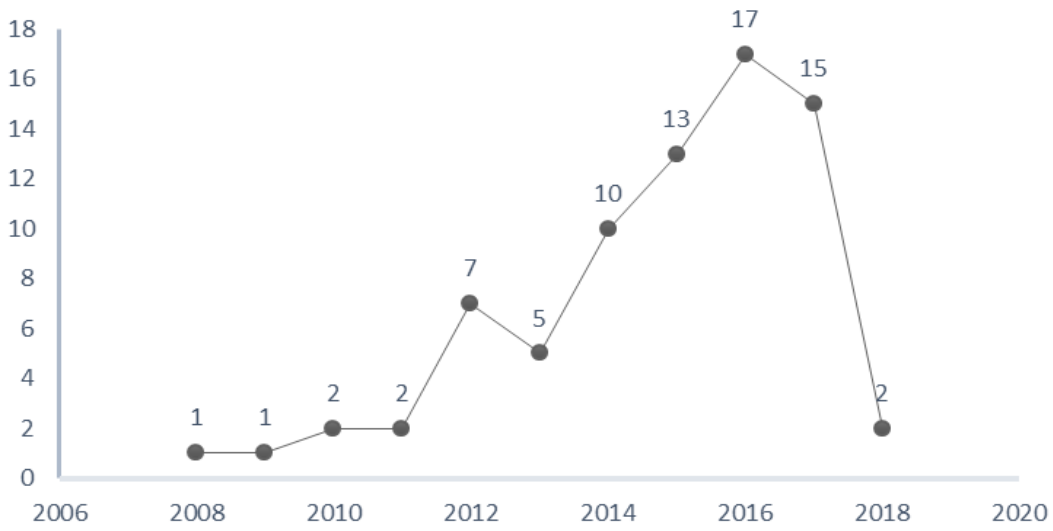


Fig. 1. Articles on BIM maturity published in the Scopus database

Regarding the source of the publications, 52% of the BIM maturity articles were conference proceedings and another 48% were journal articles. Most of the articles were published in the Proceedings of the Annual Conference of Association of Researchers in Construction Management (ARCOM; 5 articles), followed by Automation in Construction, Journal of Construction Engineering and Management, Proceedings of the European Conference on Product and Process Modelling (ECPPM) and Procedia Engineering, with 4 articles each during the last 10 years. The most productive author of BIM maturity is Succar (2009b), who published four articles, followed by Chen et al. (2014) that published three articles on BIM maturity. The contribution of the BIM maturity articles according to the country of origin where the studies were conducted revealed that 23% of BIM maturity articles are based in the United Kingdom, followed by 17% from the United States and 6% each from Australia and China. Most BIM maturity studies are concentrated in these two countries, where other countries are obviously far behind. Table 1 shows the source title, author's name and country of origin of BIM maturity articles.

Table 1. The source title, author's name and country of origin of BIM maturity articles

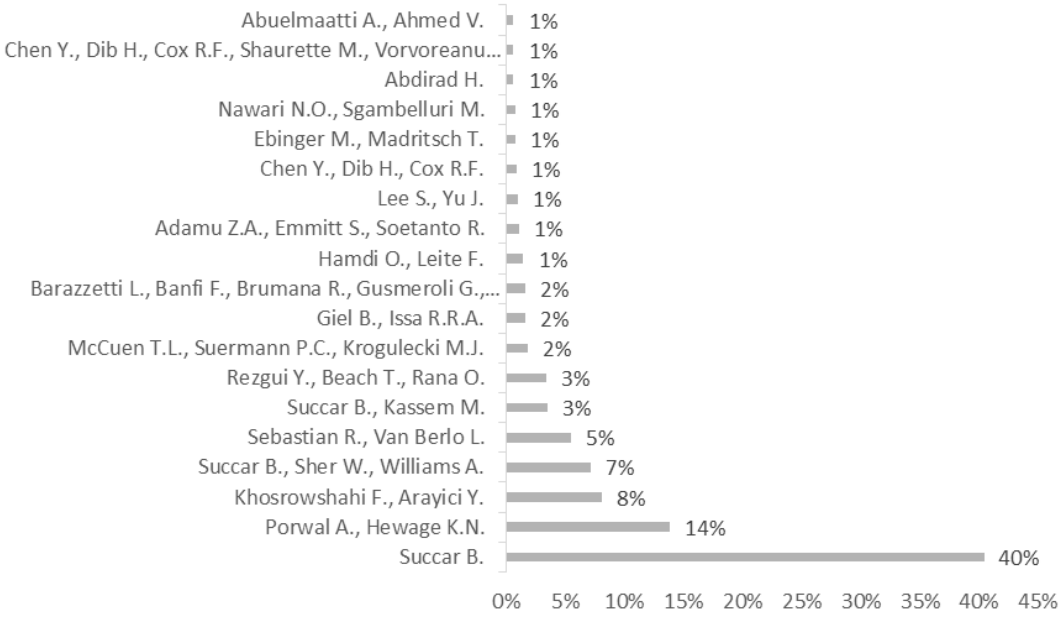
Source title	Number
Proceedings of the Annual Conference of Association of Researchers in Construction Management (ARCOM)	5
Automation in Construction	4
Journal of Construction Engineering and Management	4
Proceedings of the European Conference on Product and Process Modelling (ECPPM)	4
Procedia Engineering	4
Journal of Information Technology in Construction	3
IGLC 2017: Proceedings of the 25th Annual Conference of the International Group for Lean Construction	3
ICCREM 2016: BIM Application and off-Site Construction: Proceedings of the 2016 International Conference on Construction and Real Estate Management	3
Architectural Engineering and Design Management	3
Journal of Management in Engineering	2
Construction Innovation	2
Author's name	
Succar, B.	4
Chen, Y.	3
Cox, R.F.	3
Dib, H.	3
Ahmed, V.	2
Azzouz, A.	2
Giel, B.	2
Issa, R.R.A.	2
Kassem, M.	2
Mahamadu, A.M.	2
Merschbrock, C.	2
Penn, A.	2
Tang, L.C.M.	2
Country	
United Kingdom	21
United States	15
Australia	5
China	5
Netherlands	4
Norway	4
South Korea	4
Canada	3
Malaysia	3
Czech Republic	2
France	2
Hong Kong	2
Italy	2
Taiwan	2
United Arab Emirates	2

International Journal of BIM and Engineering Science

Available online at: http://bimarabia.com/IJBES/

December- 2018; Volume: 1 Issue: 1 **ISSN 2571-1075**

The quality of the BIM maturity articles was analysed according to the number of citations received by the authors and the source title. In total, there were 829 citations. The top three authors highly cited were first, Succar (2009b), who received 335 citations or 40%, followed by Porwal and Hewage (2013) with 115 citations or 14%, and Farzad and Yusuf (2012) with 67 citations or 8%. Figure 2 shows the percentage of citation count by authors.


Abuelmaatti A., Ahmed V. 1%
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Abdirad H. 1%
Nawari N.O., Sgambelluri M. 1%
Ebinger M., Madritsch T. 1%
Chen Y., Dib H., Cox R.F. 1%
Lee S., Yu J. 1%
Adamu Z.A., Emmitt S., Soetanto R. 1%
Hamdi O., Leite F. 1%
Barazzetti L., Banfi F., Brumana R., Gusmeroli G.,... 2%
Giel B., Issa R.R.A. 2%
McCuen T.L., Suermann P.C., Krogulecki M.J. 2%
Rezgui Y., Beach T., Rana O. 3%
Succar B., Kassem M. 3%
Sebastian R., Van Berlo L. 5%
Succar B., Sher W., Williams A. 7%
Khosrowshahi F., Arayici Y. 8%
Porwal A., Hewage K.N. 14%
Succar B. 40%
0% 5% 10% 15% 20% 25% 30% 35% 40% 45%

Fig. 2. Citations by authors

The top three highly-cited source titles were first, Automation in Construction, which received a whopping 480 citations (58%) from four articles published from 2009 to 2017; the second was Architectural Engineering and Design Management with 109 citations (13%) from three articles; and third, Engineering, Construction and Architectural Management with 67 citations (8%) from a single article. Next, are Journal of Civil Engineering and Management and Journal of Management in Engineering, both with a total of 28 citations (3%). It is important to note that the articles from conference proceedings received low citations from the academic community, the highest of which was IGLC 2017 - Proceedings of the 25th Annual Conference of the International Group for Lean Construction; only with 12 citations (1%), despite the fact that majority of articles on BIM maturity were conference proceedings. Table 2 shows the citations according to the source title.

Table 2. Citations by the source title

Journal Title	Citations	Percentage (%)
Automation in Construction	480	58
Architectural Engineering and Design Management	109	13
Engineering, Construction and Architectural Management	67	8
Journal of Civil Engineering and Management	28	3
Journal of Management in Engineering	28	3
Journal of Information Technology in Construction	17	2
Journal of Construction Engineering and Management	14	2
International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives	13	2
IGLC 2017: Proceedings of the 25th Annual Conference of the International Group for Lean Construction	12	1
Total	829	100

3.2 Defining BIM maturity

To conceptualize BIM maturity, first, a keyword search of 'maturity' was performed on the 75 articles. This exercise resulted in 26 articles; however, only 16 articles were available in full text. These articles were analysed using content analysis and the following aspects emerged; quality of use, the extent of use, the context of use and stages of processes. The word 'maturity' refers to the characteristics of BIM-able or quality of use, where it specifies the 'must have' features or areas for BIM implementation (Chen et al., 2014). The 'must have' features or areas of BIM-able denotes a specific standard or 'degrees of excellence in performing a task' (Succar, 2009b, p. 10) in delivering BIM services or products where the implementation of BIM is 'defined, managed, integrated and optimized' (Succar, 2010, p. 84). A mature company is evidence of better projection, control and performance (Chen et al., 2014). Mature information refers to the highest stage of information stability, preciseness and completeness (Zou et al., 2013). The immature stage is considered to be the initial point before progressing until achieving the highly mature stage (Sackey et al., 2013).

BIM maturity also means the extent of use of how BIM is implemented (Morlhon et al., 2015), where each BIM process advances in sequential stages of the advancement process from the early stage to the excellence stage (Ebinger and Madritsch, 2012; Liang et al., 2016). Before progressing to the desired status, the current status is the point of BIM application (Mohd et al., 2016). The identification of the current status will help identify the areas of prioritisation and improvement. An assessment of the current maturity status allows comparisons across companies, disciplines, projects, and countries to distinguish between mature and immature entities (Succar, 2009b). The assessment acts like a ranking system that identifies important areas and characteristics of each maturity level to effectively deliver BIM products or services (Chen et al., 2014). The presence of a BIM champion; an excellent BIM performance at any BIM maturity level, will guide companies or projects to advance their BIM implementation to the subsequent BIM maturity level (Azzouz and Hill, 2017).

BIM maturity also describes the context in which BIM is implemented or context of BIM use; 7 articles focused on the BIM maturity in the project, 6 articles on BIM maturity in construction companies and one article focused on the company and the industry (Khosrowshahi and Arayici, 2012), on company and project (Jung and Lee, 2016) or in all three contexts– company, project and

industry (Liang et al., 2016), respectively. Actual advantages of BIM can only be realised if BIM maturity goes beyond a single entity; signifying the existence of coordination and integration between disciplines, companies and projects (Sackey et al., 2013). Through BIM cooperation, contractor companies can be integrated into the design phase to enhance the performance of the project (Porwal and Hewage, 2013).

BIM maturity is also a stage in the processes of how BIM evolves in a company, project and industry (Liang et al., 2016). The BIM maturity for the company refers to the extent of knowledge that a company possesses to proceed with BIM implementation (attitude) based on its capability (action) throughout the project or the life cycle of the building (Succar et al., 2012). The BIM maturity for the project specifies six maturity levels from 0 (non-existent), 1 (initial), 2 (managed), 3 (defined), 4 (measured) and 5 (optimised) with the aims of evaluating how BIM is actually implemented in the project, comparing the BIM maturity across projects, and improving the project's BIM abilities by identifying the internal and external factors that are significant for the BIM implementation (Azzouz et al., 2016; Chen et al., 2016). A narrow scope of the BIM maturity for the project is an assessment of the BIM implementation in the design phase used to evaluate the capability of the design team to carry out the BIM project. BIM maturity in the design phase identifies five maturity levels: awareness of BIM, development of the BIM strategy, implementing the BIM, assessment of BIM, and sustainability of BIM implementation (Mohd et al., 2016). In the context of the construction industry, BIM maturity denotes process stages that offer a systematic framework for the classification of BIM application from pre-BIM, BIM Stage 1, Stage 2 and Stage 3 maturity levels, where it allows comparison and benchmarking of BIM implementations in various countries (Khosrowshahi and Arayici, 2012).

The above discussion showed that regardless of the context of BIM implementation, BIM maturity can be considered as a specific standard of BIM usage, which evolves through the stages of the processes from the initial immature stage to the advanced level of providing services or products.

3.3 BIM maturity models

To identify BIM maturity models, a search using "maturity model" and "BIM maturity model" was performed on the 75 articles and 17 articles were generated, with 14 full-text. The top four most frequently quoted BIM maturity models are the National BIM Standard Capability Maturity Model (NBIMS-CMM), BIM maturity (BIMM), BIM proficiency matrix and BIM implementation models. Content analysis of the 14 full-text articles was performed to explore the details about the models.

The commonly adopted maturity models originate from the capability maturity model (CMM) used in the manufacturing sector to assess and enhance software development (Chen et al., 2014; Dib et al., 2012). These maturity models follow a sequence of the distinct path with various stages (Liang et al., 2016). Two-thirds of the above full-text articles reported about the NBIMS-CMM, developed by the National Building Information Model Standard (NBIMS) for the construction industry. NBIMS-CMM is the first BIM maturity assessment model and aims to guide managers to access their business and processes to reach the threshold of BIM-able (Chen et al., 2014; Azzouz and Hill, 2017). The model is

centred on the management and the data features in the BIM system (Dib et al., 2012). NBIMS-CMM measures the construction professionals' current BIM capabilities and how to progress to the subsequent maturity level (Wu et al., 2017). NBIMS-CMM consists of 11 capability areas. The total score of all capabilities will provide the maturity level of BIM users, ranging from non-certified (< 30), minimum BIM (30 – 49.9), certified (50 – 69.9), silver (70 – 79.9), gold (80 – 89.9) to platinum (90 – 100) (McCuen et al., 2012). Using NBIMS-CMM, Morlhon et al. (2015) identified the important factors and actions needed to successfully progress in BIM. NBIMS-CMM was used to evaluate the winners of the 2008 Architectural Practice BIM Award in the United States and found that the winners were at BIM level 1 or visualization (McCuen et al., 2012).

BIMM was quoted in 58% of the articles. Succar (2009b) introduced a comprehensive BIM maturity that consists of BIM capability, BIM stages, BIM competency sets and a roadmap to achieve the main goal of BIM implementation; integrated project delivery. BIM maturity begins with the pre-BIM level and the model can also be used to measure BIMM at the macro (market and industry), meso or the middle level; between the macro and micro (project teams) and micro (companies) levels (Succar, 2009b; Liang et al., 2016). Sackey et al. (2013) expanded the BIMM model to cover the vital processes of BIM implementation for construction companies in parallel with the maturity levels. The authors indicate two important stages – brainstorming and manifestation stages, and their work resulted in a micro level of the BIM implementation framework for construction companies. Using the BIM maturity assessment, Smits et al. (2017) analysed the impact of the BIM implementation on the performance of construction companies in the Netherlands. Their study revealed that only the BIM strategy is conceptualised as the company's mission and vision on BIM, top management commitment, BIM advocates, and the existence of BIM planning team is the determinant for the company's project performance. Azzouz and Hill (2017) used BIMM to identify BIM best practices in 1291 Arup's projects: a global group of architectural, engineering and contracting companies as a driving force for innovation across countries, disciplines and project teams.

The BIM proficiency matrix was identified by 42% of the articles. The BIM proficiency matrix was developed by the Indiana University in 2009 to measure the extent of BIM, developed and used by companies, or in simpler words: the extent to which companies adopt BIM (Chen et al., 2014; Jung and Lee, 2016). It emphasizes on information and BIM products (Chen et al., 2016). It comprises of 32 credit areas with 5 maturity levels: a score of 0 indicates the absence of BIM and a score of 1 demonstrates a complete implementation of BIM (Wu et al., 2017).

The BIM implementation model was acknowledged by 33% of the articles. It measures the BIM adoption rate in the construction industry on a countrywide scale and was used in surveys conducted in the United States, Canada, Western Europe and South Korea (Jung and Lee, 2016). One of the weaknesses of the model is that it measures the number of BIM users instead of the depth of the BIM implementation in the industry, and the information can be misleading if the survey excludes non-users (Jung and Lee, 2016). The BIM implementation model is not suitable for assessing BIM maturity at the company and project team level, since the model cannot guide a company or project team to improve its BIM output or to progress to the next BIM level (Succar et al., 2012).

It is worth mentioning that most BIM maturity models have not been evaluated for their contents' accurateness, inclusiveness and superfluous (Abdirad, 2017). Both empirical and practical evidence of the models' predictive ability will be valuable in guiding the practitioners on how to increase their project's and company's BIM maturity levels. Except for BIMM, most models were developed for specific purposes, ignoring the entire construction supply chain; therefore, they are only available to specific users (designers, quantity surveyors or clients). As a result, these models cannot be used for benchmarking or comparing BIM maturity between project teams and companies. Another drawback of the models is that the weights of each indicator were adjusted based on the countries where the tools were developed (Kassem and Succar, 2017; Kassem et al., 2013). Taking into account that most of the construction players in developing countries have not yet implemented BIM and that BIM projects are mostly concentrated in public megaprojects (Latiffi et al., 2015; Ramachandran, 2016), only models that consider pre-BIM maturity such as NBIMS-CMM, BIMM and the BIM Proficiency Index are suitable for assessing BIM implementation in these developing countries. The following section discusses the indicators for measuring BIM maturity.

a. Indicators for measuring BIM maturity

Several authors emphasise the importance of identifying BIM maturity indicators to facilitate the assessment of the extent to which projects, companies and industry have implemented BIM and how BIM implementation can be improved and progressed. At the moment, authors are not in agreement on the BIM maturity indicators where various indicators were proposed due to the multidimensional of BIM usage (Chen et al., 2016). McCuen et al. (2012) identified 11 items for measuring BIM maturity in winning BIM projects using the NBIMS-CMM, namely i) data richness, ii) life-cycle views, iii) disciplines, iv) change management, v) business process, vi) response, vii) delivery method, viii) graphical information, ix) spatial capability, x) information accuracy and xi) interoperability. These 11 items are related to information and do not cover the other facets of BIM such as people and organisation. Succar (2009b) and Liang et al. (2016) identified three indicators for BIM maturity; Technology, Process, and Policy or Protocol, Chen et al. (2014) identified four indicators; Information (information management and delivery), Process (process definition and management), People (training) and Technology, while Wu et al. (2017) acknowledged five indicators; Technology, Process, Policy, People and Organisation. A review article by Abdirad (2017) identified the BIM inputs, the BIM process, the BIM output and the BIM performance at the organisational, project and industry level as the indicators for measuring BIM maturity. The author conceptualises BIM input as BIM Technology (general BIM technology, software, visualization tools) and BIM Users (competencies, motivation, training and satisfaction). The BIM Process consists of two types of interactions – human to human and human to computer; BIM output measures the quality and quantity of the project's performance (time, cost and standard) and the life cycles of the facilities (durability, cost and function).

Technology refers to software, hardware and data network (Succar et al., 2012). Process denotes the resources, actions, workflows, management and leadership that plan, design, execute and deliver BIM products and services (Succar, 2009a). Policy or protocol means written or unwritten standards, rules, specifications, contracts, guidelines, risk-sharing agreements and supervision (Liang et al., 2016;

Succar et al., 2012; Wu et al., 2017). People mean the qualities of BIM staff, such as their competencies, attitudes and training (Wu et al., 2017). Information represents information guarantee, conveyance method and management, including work flow, life cycle process and geospatial ability (Chen et al., 2014), while the organisation measures the organisational support, leadership commitment, BIM culture and strategies (Wu et al., 2017). The BIM output is the outcome of performing BIM. In the context of the project, cost reduction, speedy completion, improvement of sustainability and functionality are examples of BIM output indicators in the project (Abdirad, 2017). In the context of the company, the examples of BIM output are the actual cost of investment, return on investment, ability to deliver on time, stakeholder satisfaction, and ease of use (Abdirad, 2017). In the context of the industry, growth in BIM implementation, investment, BIM training, and knowledge are some examples of indicators for BIM output (Abdirad, 2017).

The author identified different indicators for assessing BIM maturity for the context of BIM use; the personnel, the company, the project and the industry. All seven indicators (Information, People, Policy, Process and Technology, Organisational and BIM output) were proposed for assessing BIM maturity in the company and the project. Six indicators were identified for assessing the BIM maturity in the industry, and Policy, Process and Technology indicators were used to assess BIM maturity in the personnel.

In short, there are seven major indicators for assessing BIM maturity, namely Information, People, Policy, Process, Technology, Organisation and BIM output. Table 3 summarises the indicators used by the authors and context for assessing BIM maturity. The table shows that the majority of the authors identified Technology and Process as the first top indicators for measuring BIM maturity, followed by Information, People and Policy.

Table 3. Indicators for assessing BIM maturity

Author	**Indicators**						
	Information	People	Policy	Process	Technology	Organisational	BIM output
McCuen et al. (2012)	X						
Succar (2009b)			X	X	X		
Liang et al. (2016)			X	X	X		
Chen et al. (2014)	X	X		X	X		
Wu et al. (2017)		X	X	X	X	X	
Abdirad (2017)	X	X		X	X		X
Context							
Personnel			X	X	X		
Company	X	X	X	X	X	X	X
Project	X	X	X	X	X	X	X
Industry	X	X	X	X	X		X

Despite the many indicators, only a few studies validate the theoretical models of measuring BIM maturity. McCuen et al. (2012) used NBIMS-CMM to evaluate the BIM award winning projects in the United States for the year 2008 and acknowledged that Graphical Information, Data Richness and Interoperability are the top three important Information indicators to evaluate to what extent the projects implement BIM. Graphic Information measures the presence of graphics, 2D drawings plus intelligent or 3D object-based with time and cost data. Data Richness refers to the robustness of the

information in BIM, while Interoperability refers to the ability to share information without data loss or misinterpretation. Chen et al. (2014) used a confirmatory factor analysis and verified that, although all indicators (Information, People, Process and Technology) were important, most of the BIM implementations were towards Process and Information. Subsequently, Chen et al. (2016) tested three indicators – Technology, Process and Information using structural equation modelling on BIM projects and identified that Process is the most important indicator for evaluating BIM maturity.

4. Conclusions:

This paper discusses the trends of BIM maturity studies, identifies the available models of BIM maturity and the indicators for measuring BIM maturity. Most articles on BIM maturity were published by authors from the United Kingdom and the United States, but the top three authors highly cited were from Australia, Canada and the United Kingdom. The result reveals four aspects of BIM maturity conceptualisation: the quality of use, the extent of use, the context of use and stages of processes and the four most frequently quoted BIM maturity models are NBIMS-CMM, BIMM, BIM proficiency matrix and BIM implementation models. The result highlights seven indicators for BIM maturity assessment, namely Information, People, Policy, Process, Technology, Organisation and BIM output, with Technology and Process as the two top indicators used by researchers. The results acknowledge that the indicators are not the same for assessing the personnel, the company, the project and the industry.

Clearly, more work is still needed to demonstrate if these BIM maturity models can assess the extent of BIM implementation and identify the important indicators for BIM to improve and progress in projects, companies and industries. Specifically, there is a dearth of studies from the developing world and that focus on People, Policy, Organisational and BIM output indicators. The People factor; essentially, the attitude of employees and project team members towards technology advancement and communication behaviour were identified as dominant in ensuring the progress of BIM (Bosch-Sijtsema et al., 2017; Ahmed and Kassem, 2018). The Policy factor, such as the client's contract statement for BIM-led project, where key project members have similar access and control over the information exchange process, has been proven to minimise rework and faster completion (Park and Lee, 2017). In a project where BIM implementation is concentrated in the design and construction phases, the success of BIM will depend to a large extent on the understanding and communication of project managers, architects and contractors (Arayici et al., 2011); to which Vass and Gustavsson (2017) postulate as intra and inter-organisational challenges. Similarly, people and organisational factors were acknowledged as the most challenging when implementing BIM (Porwal and Hewage, 2013). Equally important is the BIM output factor, which provides tangible proof of the actual benefits of BIM. Insufficient evidence of a positive impact of BIM maturity on project's productivity is argued to be one of the reasons for BIM's slow progress in construction projects and companies (Smits et al., 2017).

This study extends the literature on the BIM maturity assessment models by identifying the indicators for assessing the extent of BIM use by companies, projects and industries. The study points out the gap to guide future studies. The results act as a reference tool to assist BIM users or potential users in identifying the starting point for their BIM usage or to plan for the necessary improvement of BIM

utilisation.

Several limitations can be found in the study; first, the review did not include the web of Science (WoS) database due to its inaccessibility to the authors. Future reviews should include the WoS database in adding to the breadth of the study. Second, the terms 'BIM and maturity', 'building information modelling and maturity' and 'information modelling and maturity' were used to search for articles for the systematic review. Future studies should include other terms such as 'BIM implementation assessment' or 'BIM matrix' to uncover the BIM models that may be practiced in the industry.

Acknowledgements:
The authors sincerely appreciate the financial support from the Universiti Sains Malaysia through the Graduate on Time Incentive (Grant number: 1001/PPBGN/821054).

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International Journal of BIM and Engineering Science

Available online at: http://bimarabia.com/IJBES/

December- 2018; Volume: 1 Issue: 1 **ISSN 2571-1075**

BIM Performance Improvement Framework for Syrian AEC Companies

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Abstract:

The Architectural, engineering, and construction (AEC) industry projects in Syria struggled with myriad problems. However, Building Information Modelling (BIM) technology worldwide proves its capability to solve these issues, Syrian AEC companies are rarely using BIM. Therefore, the aim of this study is to improve the BIM performance in Syrian AEC companies which are already in the BIM zero level and to provide strategies to the companies which do not use BIM for BIM adoption in their projects. An extensive literature review has been conducted to investigate the latest strategies and frameworks to implement and improve BIM performance. In addition to, an online questionnaire analysed by SPSS software and Excel to develop the suggested framework. Furthermore, the General Company for Engineering Studies and Consultations (GCEC) is selected as a case study to validate the framework. This study assessed and enabled the company to improve its BIM performance by using BIM maturity matrix (BIM3) through three stages: 1) Identified BIM and its performance, 2) Performance measurement, 3) Performance improvement. This study provides a new and novel companies' BIM performance improvement framework which consisted of three fields: policy, process, and technology. The results of this study assisted to identify, obtain, and improve BIM interactions between individuals and companies to enhance the collaboration between all project participants. The future research will attempt to test and validate the proposed framework for private sector companies.

Keywords: BIM Maturity; AEC; Syria; Performance Improvement; Policy; Process; Technology

1. Introduction:

The AEC industry plays a vital role in Syria's socio-economic growth (Ahmed, S., et al., 2014). However, the AEC industry in Syria facing myriad issues such as schedule delays, over budget, low quality, lack performance, poor productivity, and less efficiency (Ahmed, S., et al., 2014, Hassan, B., et al., 2010). In the last two decades, developed countries used BIM to mitigate, overcoming those problems, and benefit from the advantages of BIM implementation (Elhendawi, A.I. 2018).

Currently, Performance management and measurement are unused as a performance improvement tool in Syrian AEC projects, However, Performance measurement is the first and the essential step to enhance the AEC projects performance (Maya, R.A., 2016). In addition to that, BIM maturity level in Syrian AEC projects is still in level 0, which means that there isn't significant BIM implementation in Syrian AEC projects. Furthermore, there is lack of researches relevant to BIM in the AEC industry in Syria and the awareness about BIM is very low.

Therefore, this study aims to develop a BIM performance improvement framework in AEC industry companies in Syria. To achieve this aim, a methodology consisted of three stages are followed. The first stage is an extensive literature review followed by an online survey which investigates the AEC industry projects participates perspectives on the key factors influencing BIM implementation which

December- 2018; Volume: 1 Issue: 1 **ISSN 2571-1075**

represent strategies for AEC industry companies to adopt BIM. Whereas, the third stage is the observation of the GCEC's behaviours, capabilities and its engineers and decision makers perspectives on BIM performance improvement as a case study.

This study provides a framework to improve the BIM performance within the Syrian companies scale. The proposed framework provides clear strategies and a better understanding of BIM and its fields (Technology, Process, and Policy) to facilitate the gradual transition of the Syrian AEC industry companies towards the BIM.

2. Literature review:

Overview:

There is no precise BIM definition every expert or researcher defined BIM as his perspectives'. Succar, B., (2010a), defined BIM as "*a set of technologies, processes, and policies enabling multiple stakeholders to collaboratively design, construct and operate a facility in virtual space*". However, Autodesk, (2018), argued that "*BIM is an intelligent 3D model-based process that gives architecture, engineering, and construction (AEC) professionals the insight and tools to more efficiently plan, design, construct and manage buildings and infrastructure"*. In spite of that, the different definitions emphasis that BIM help all AEC projects participants to collaborate in an intelligent environment to improve the projects efficiency, performance, and achieving the stockholder requirements.

Succar, (2010a) claimed the BIM field as: technology, process, and policy. BIM policy is the field of interaction generating the best practices for the purpose of saving benefits and minimizing conflict between BIM stakeholders. The BIM Process is the field of interaction generating and maintaining building information models. The BIM Technology is the field of interaction to generate and maintain building information models. See "Figure 1".

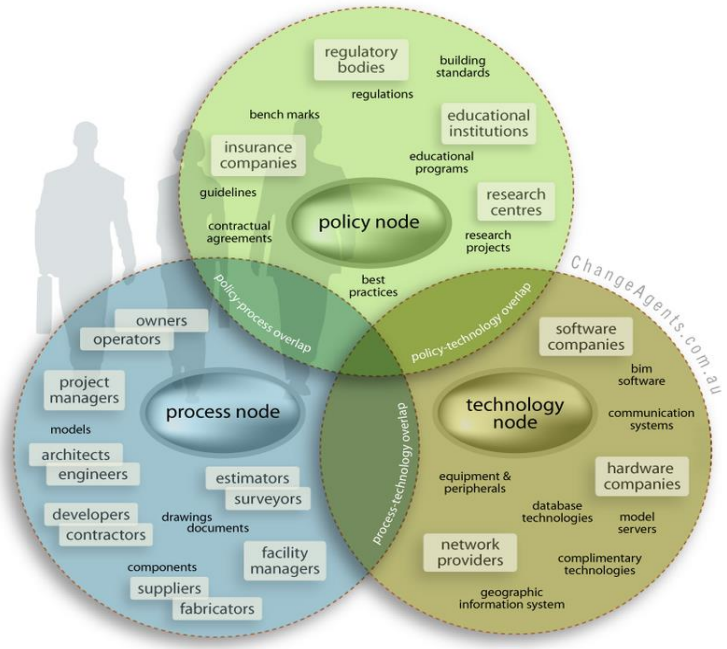

Figure 1: The interlocking fields of BIM activity(Succar, B., 2010)

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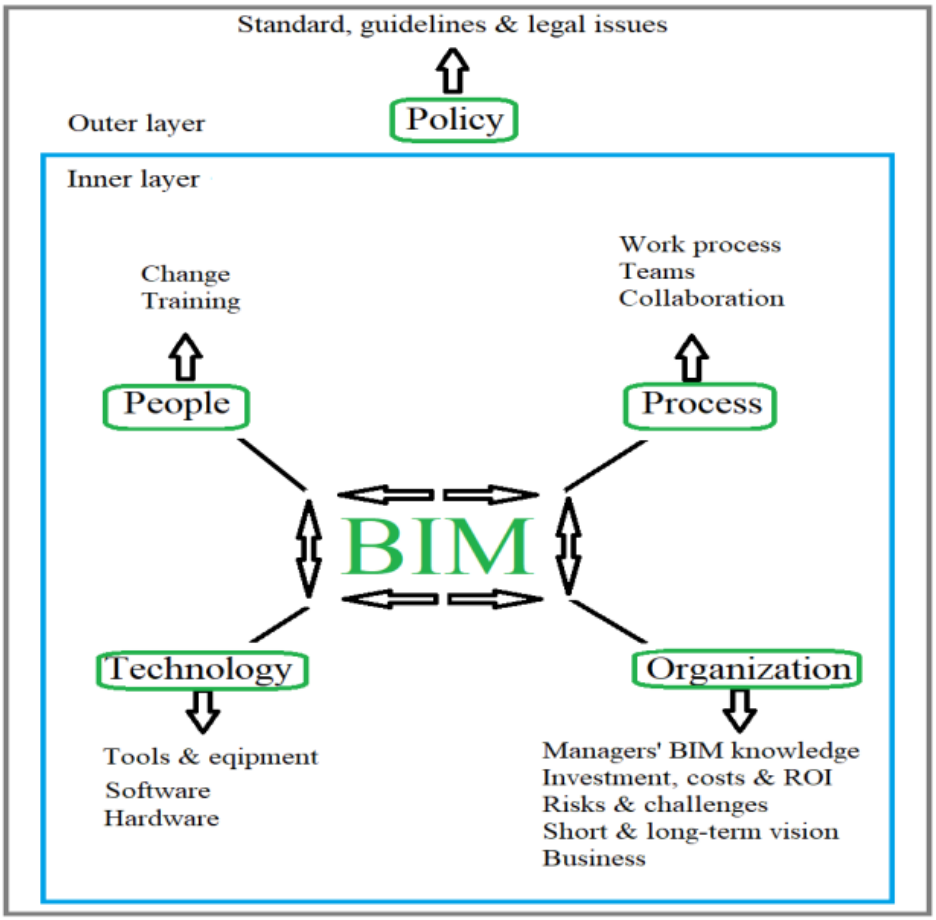

Figure 2: The key factors and BIM fields (Koucha, A.M. et al 2018)

On the other hand, Succar, B., (2010a) defined the BIM Performance as the ability to deliver BIM-enabled outcomes:

- Unique outcomes: clash detection, code checking, and constructability of complex geometries.
- Improved outcomes: coordinated drawings, improved prefabrication, more accurate costs.
- Increase productivity: better design, better quality, and better service. And reduce waste: less rework, less physical waste, less conflict, waste of time.
- It is the ability to improve certainty: cost certainty, time certainty.
- Enable fast-tracking: construction sequencing, collaborative workflows.
- Reduce environmental impact: thermal analysis, carbon footprint.

Therefore, to improve the companies' BIM performance, all the BIM outcomes must be gained with high quality, certainty, and efficiency.

Whereas, McPartland, R. (2018) argued that the BIM outcomes different according to the BIM level. the AEC industry witness myriad evolution in its developing journey starting with the hand sketch and the computer aid design (CAD) into the digital age. The BIM levels terminology refers to the level of maturity within implementing BIM in the country or in AEC Company which has the range from 0 to 4. McPartland, R. (2018) claimed that there are four BIM maturity levels as follows:

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- Level 0 BIM: referred to no collaboration, 2D CAD drafting, and use paper or electronic prints. The majority of the AEC industry is in this level (NBS, 2017).

- Level 1 BIM: 3D CAD or Modelling 3D. Common Data Environment (CDE) such as electronic document management system (EDMS) should be implemented, to allow the exchange of the information between all the project players.

  To achieve Level 1 BIM, It should be achieved the following: 1) Roles and responsibilities should be agreed upon, 2) Naming conventions should be adopted, 3) maintain the project-specific codes and project spatial coordination.

- Level 2 BIM: featured by collaborative environments, and demand an information interchange process and harmonious between various systems and project stockholders.

- Level 3 BIM: UK Government provides a Level 3 Strategic Plan which identified key features for this level as follows: 1) international 'Open Data' standards, 2) A new contractual framework, 3) a unified cultural environment seeks to learn and share, 4) Training the public sector clients, 5) Driving local and global growth and jobs in BIM.

Mark Bew and Mervyn Richards, in 2008, developed a BIM Maturity Diagram as shown in figure 3 (Sinclair, S., 2012). *The* diagram acknowledges the impact of both data and process management on BIM and defines various levels of maturity for BIM (Sinclair, S., 2012).

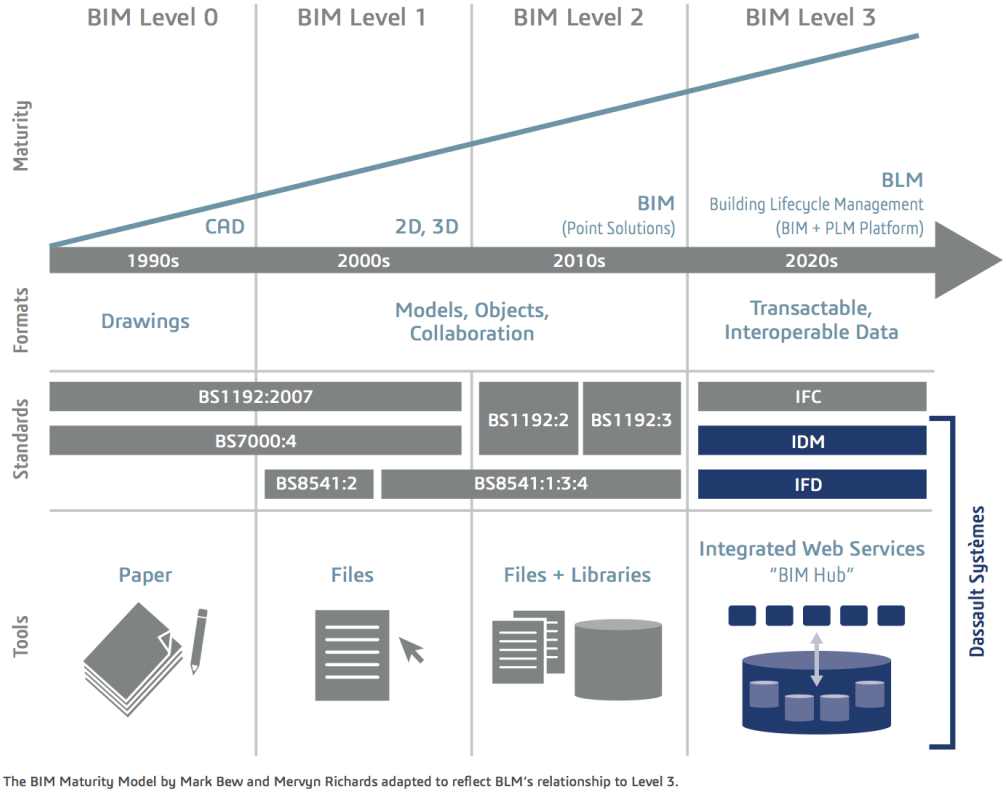

Figure 3: BIM Maturity Levels by Bew –Richards (BIMIWG, 2011)

However, the current BIM knowledge level of Syrian construction companies and engineering is very low, it expected that the full adoption of BIM in Syria will be within the next five years [2].

Ahmed, S., et al. 2018 claimed that BIM is most appropriate to the design stage, and it can be used in the construction stage. However, several researchers claimed that BIM is suitable for all the project stages (Omar, H.S., 2015, Elhendawi, A.I., 2018). Whereas Ahmed, S., et al. 2018 claimed that BIM can solve 50-75 % of the current AEC industry projects problems, Omar, H.S., 2015 added that BIM enhances the industry performance and efficiency.

On the other hand, Omar, H.S., 2015 claimed that the key barriers that impeded BIM implementation are: 1) lack of Management adhering to applying BIM, 2) the resistance to change, and hang on to the old methods of working. However, Ahmed, S., et al. 2018 categorized the barriers and challenges that hinder the application of BIM into economic, technical, organizational, legal, human challenges, and the risks associated with using a new technology.

However, Ahmed, S., et al. 2018 claimed that the main factors influencing the BIM adaption in Syria are: 1) including BIM in university curricula provide a new BIM expert generation of Syrian engineering, 2) Syria government support is the main engine for the BIM adoptions, 3) The designers play a vital role to adopt and convince others project parties about the benefits of BIM throughout the projects life cycle, 4) Prepare a time plan to training the BIM unqualified staff, 5) provide standard to deal with the principles and techniques of BIM. Omar, H.S., 2015 and Elhendawi, A., (2018) summarized these factors as: 1) Raising the awareness of BIM to motivate all the AEC players to mandate BIM, 2) The government can play a vital role to introduce appropriate execution plans to implement BIM stipulating a timeframe to mandate BIM as a compulsory requirement in the AEC industry, 3) Including BIM in the AEC undergraduate and postgraduates' syllabuses to present to the AEC industry a new BIM experts generation, 4) Surrounding environment and competitive pressure, 5) Flexibility to change.

Moreover, the absence of guidance for organizations looks forward to adopting BIM hinder the organizations to implement BIM. Successful implementation of BIM requires identifying the current status of the organizations in several aspects, such as the qualifications, capabilities, and willingness of staff to move to this new system (Amaratunga, D. and Baldry, D., 2002). In addition to the desire of the administration to adopt and its readiness to set a special budget to improve the reality of the organization to soft transfer to better levels that help in adopting BIM technology and benefit from it.

BIM Evaluation and assessment:

Maya, R.A., (2016), recommended that the Syrian companies have to use project management techniques and IT, increase training activities and use advanced tools to enhance the construction projects performance. Several researchers defined BIM as project management techniques (Omar, H.S., 2015, Succar, B., 2010b) and other argued that BIM as a project management tool (Autodesk, 2018). Therefore, BIM is suitable to improve AEC projects performance.

Several researchers developed BIM assessment frameworks as follows:

I-CMM BIM assessment framework:

As the earliest and most used assessment framework in the US, the National Institute of Building Science proposed the BIM Interactive Capability Maturity Model (I-CMM) based on 11 criteria (data richness and information accuracy etc.) with 10 capability maturity levels for each. It intends for

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'users to evaluate their business practices along with a continuum or spectrum of desired technical level functionality' as well as 'for use in measuring the degree to which a building information model implements a mature BIM Standard'. Regarding its single aspect of assessment in information management, it is not for any benchmarking purpose or for 'BIM implementations comparison' (Kam, C., et al., 2013).

BIM proficiency Matrix (BPM):

In order to evaluate the individual's BIM skill proficiency, for both designers and contractors Kam et al., 2013) developed a BIM proficiency Matrix (BPM) with eight categories and each category has been divided into four maturity levels. A score is also presented with associated certifications. From the present author's view, there is not enough information available for research purposes or validation processes to test its validity. Kam believes this assessment method lacks social aspect consideration.

BIM3 – Succar BIM assessment framework:

Succar, B., 2010a developed a BIM Maturity Matrix (BIM³) as 'a knowledge tool which incorporates many BIM Framework components for the purpose of performance measurement and improvement'. Measurement provides the basis for a company to assess how well it is progressing towards its planned aims, help to identify areas of strengths and weaknesses and decides on future recommendations. The BIM³ has two axes - BIM Capability Sets and the BIM Maturity Index [20]. BIM Capability refers to the minimum abilities of an organization or team to deliver measurable outcomes. BIM Maturity refers to the gradual and continual improvement in quality, repeatability, and predictability within available BIM Capability BIm3 contains five components (Succar, B., 2010b) as BIM capability Stages representing transformational milestones along the implementation continuum.

1. BIM maturity levels representing the quality, predictability, and variability within BIM Stages.
2. BIM competencies representing incremental progressions towards and improvements within BIM Stages.
3. Organizational scales representing the diversity of markets, disciplines and company sizes
4. Granularity levels enabling highly-targeted yet flexible performance analyses ranging from informal self-assessment to high-detail, formal organizational audits.

BIM Characterisation Framework (Gao, (2011)):

Gao, (2011) proposed a characterisation framework for BIM, with the intention to understand how BIM should be conducted and who should be involved. This framework has divided BIM-based project information into 3 categories, 14 factors and 74 measures.

Organisational BIM assessment framework (Kreider, (2011)):

A BIM maturity framework from client/facility owner's perspective was developed by Kreider (2011) for organisational BIM (OBIM) usage. This assessment framework contains six main areas: strategy, uses, process, information, infrastructure and personnel's BIM competency.

This study selects BIM3 – Succar BIM assessment framework due to being simplified and appropriate to the selected company scale and capabilities.

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Strategies and frameworks for BIM implementation:

Several researchers developed many Strategies and frameworks for BIM implementation such as the following:

BIM framework for practical implementation (Jung, Y. and Joo, M., 2011):

Jung, Y. and Joo, M., (2011), developed a framework with six major variables classified into three dimensions in a hierarchical structure. The three dimensions include 'BIM technology', 'BIM perspective', and 'construction business functions' as illustrated in Figure 4.

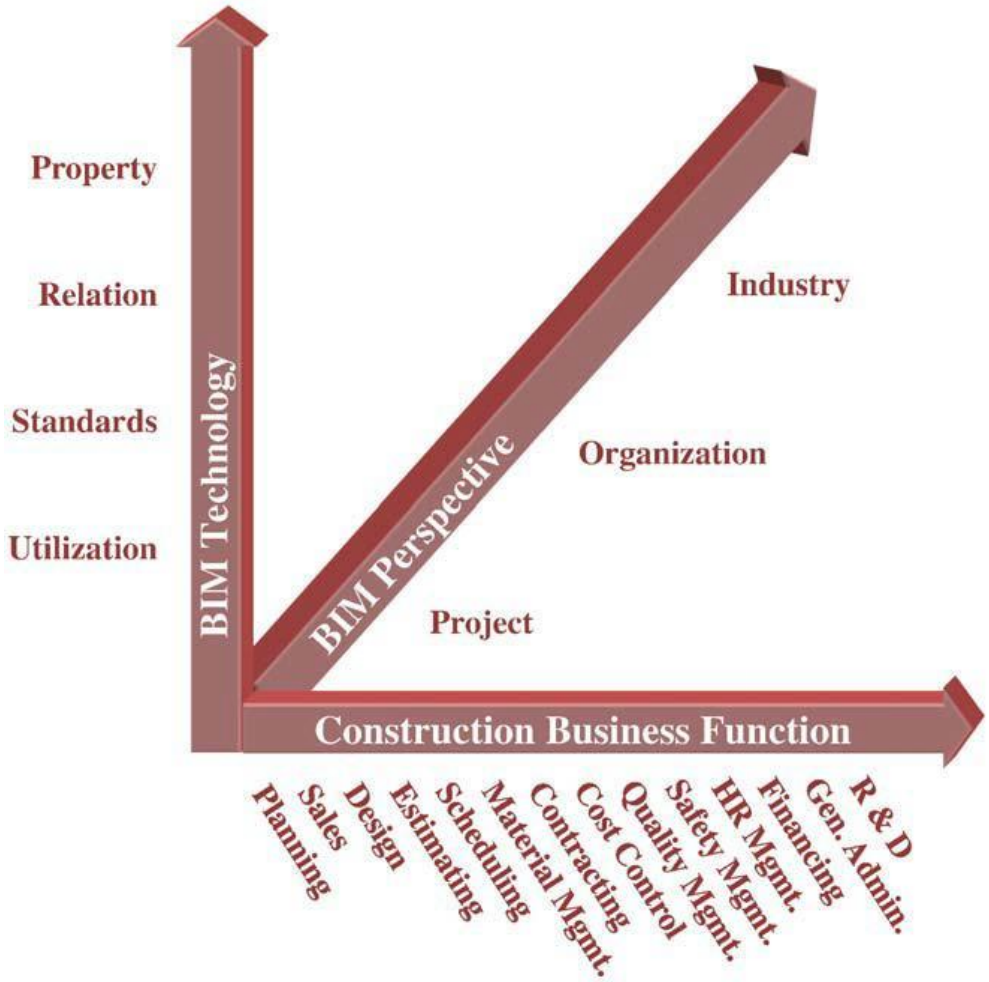

Figure 4: BIM framework for practical implementation (Jung, Y. and Joo, M., 2011) [10]

Jung, Y. and Joo, M., (2011)'s framework can be used as evaluation criteria for BIM's practical Implementation within different BIM perspective (Project, Organization, and Industry). This study trying to find framework more appropriate to organization scale.

In spite of, Koucha, A.M. et al, (2018) suggested a framework to implement BIM which consisted of three steps namely: understanding, Planning, and piloting. As shown in figure (5).

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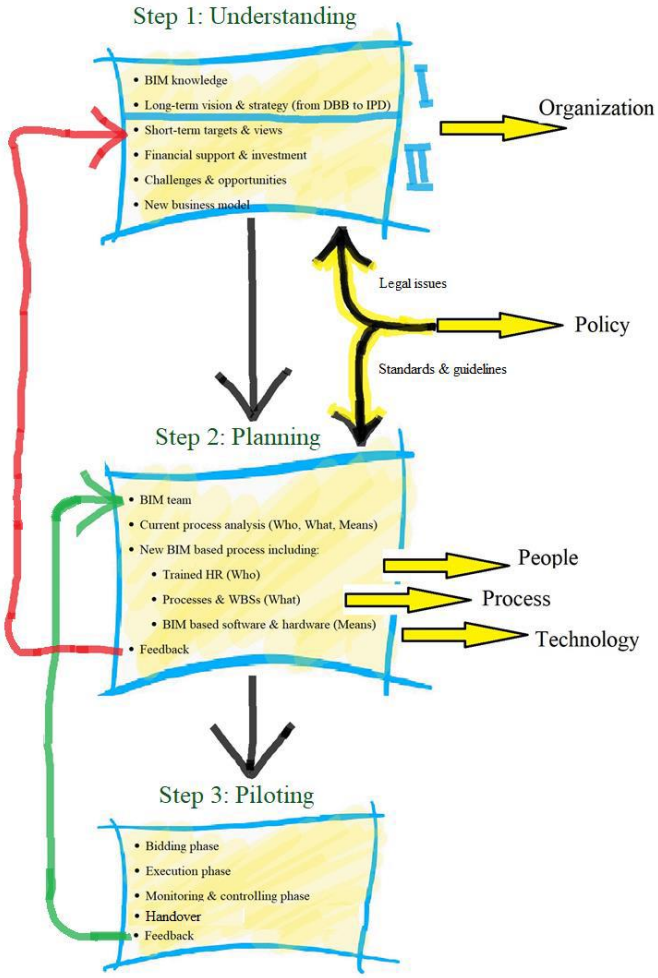

Figure 5: BIM implementation framework (Koucha, A.M. et al 2018)

Koucha, A.M. et al, (2018) framework is limited to an initial BIM implementation framework for small and medium contractors companies. Therefore, there is a need for a framework deals with different types of companies including the scale of the large company.

There are a few types of research related to BIM in the AEC industry in Syria. Thence, there is a knowledge gap about a framework or a strategy to implement BIM. This research tries to fill this gap to provide a framework to BIM performance improvement in AEC industry Syrian companies.

3. Research Methodology:

The methodology includes three stages: reviewing the literature, conducting a questionnaire, and observation a case study, as shown in Figure 6. **The first stage:** an extensive investigation for the literature review to build a deep understanding to cover the stipulated research scope. **The second stage** is collecting and analyzing the data from an online questionnaire to develop the proposed Framework.

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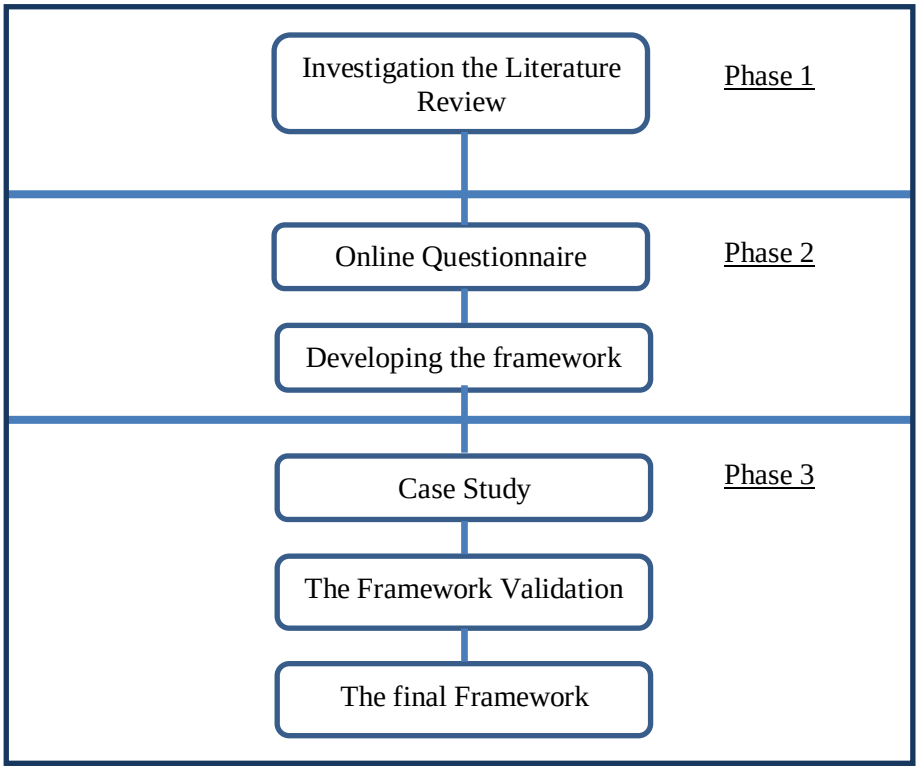

Figure 6: Research Methodology

The questionnaire consisted of 34 questions, 89 corrected received responses from respondents. It represents a segment of the Syrian engineers in several governorates which reflects Syrian position in the current circumstances. The result emphasized that 50% of the respondents aware of BIM and 23.8 % have worked on at least two projects related to Modelling. This means the tendency towards the philosophy of building information modeling for the new generation of Syrian engineering, indicating the potential evolutionary power of this philosophy over the next few years.

The respondents hold a varying degree from Bachelor to Diploma, Master and Ph.D. in Engineering in most of its specializations which represent the whole Syrian AEC projects participants. The most of them are civil engineering (60%), followed by architectural (25.8%), mechanical, electrical and others. The majority of respondents were designers, project managers, consultants and other working groups in several different companies: studies, Execution, Syrian Universities, and Engineers Syndicates located in several governorates. In addition to, some private engineering offices, buildings belonging to the Ministry of Health, Culture, Tourism, Ministry of Public Works, Ministry of Housing and others.

The majority (80 %) of the respondents exceeded 15 years of experience and 20% of them are still in the range of 2 to 5 years. the most of the respondents (30%) work in the field of residential construction and 26% work in the education sector, represented by the Syrian universities spread throughout the Syrian territory.

The conducting survey covers BIM adoption between Syrian engineers and both public and private building sector; the result represented that 57% of responders consider their selves as BIM users

(Figure 7), but in fact, they know a little about BIM. In spite of this, 44% think that Syria can be adopted BIM during the next five years. With emphasizing to the government role in the compulsory mandate of BIM. Revit is the most famous BIM tool among Syrian engineers; about 61% of the respondents believe that BIM can be useful in the design stage while 21% indicated that they can implement BIM in both design and construction stage of the project. Unfortunately, due to the lack of the budget allocated for the training and rehabilitation of employees, or fear of the high cost of adopting this technology and the use of programs. 31% of staff rely on self-training, and only 24% of them receive formal training in addition to their effort.

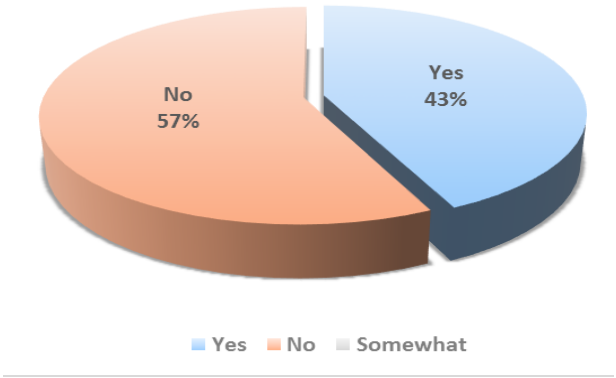

Figure 7: Percentage of BIM users

The third stage: General Company for Engineering Studies and Consultations (GCEC) has chosen as **a case study** to measure its reality and readiness to begin a gradual plan towards adopting BIM. The reason for choosing is: GCEC is the largest and most important company in Syria in the designing field. The GCEC is committed to quality, excellence and continuous development in its performance and a high level of creativity and innovation, and the application of commercial quality standards through a team of integrated technical engineers and administrators with a brilliant experience. The company's staff consists of 2190 employees working in locations spread throughout Syria. The director of GCEC- Branch of Coastal Zone is interested in keeping pace with the scientific developments, and the introduction of modern technology. The company team used the BIM tool Revit from 2006 which gave them an idea about the new technology, and the high benefits that a company can gain by adopting BIM. This study dealt with the Coastal Zone Branch as a first step towards pushing other institutions to go for competition.

There are three measurement scales according to BIM performance measurement overview established by (Ahmed, S., et al., 2014): Individual, Organizations, and Markets. This study used the *Organizational Capability & Maturity* scale by developing a strategy by using BIM Maturity Matrix "BIM3". By using it, this study provides some recommendations in three BIM fields: Technology, Process, and Policies. The BIM3 is intended for low-detail organizational self-assessment. For best results, must follow the below-recommended steps:

- Identify the best person to lead the assessment effort – someone with significant experience in BIM tools, workflows and protocols and sufficient insight into the organization' systems.
- Manner this assessment as a group activity, a workshop with 3-9 individuals representing punishments and seniority levels.
- Set aside one hour to complete the self-assessment exercise and its follow-up discussions.

The matrix has translated into the Arabic language and presented to a group of experienced engineers in the company (GCEC); a meeting held between them and the researchers, to explain the matrix and

its working structure. The engineers were asked to apply the precise method of processing and answering accurately for each cell after reading all the cells of each group, and to put a signal to clarify the cases achieved in the company after reading the entire line of each capability. The numbers placed under each cell are intended to determine exactly where the problem is and to discuss solutions, not to give an indicative number and computational ratio.

As a result of the above three stages, the study enhances the Performance improvement and providing recommendations according to the performance measurement mention above.

4. Results:

Questionnaire (Developing the proposed Framework):

The respondents (49%) claimed that BIM has the ability to solve 50-75% of the current building problems. This result is as similar to what Elhendawi, A., (2018) said. In addition to that, 37% of the respondents believe that BIM should be compulsory under the guidance of the government, which is considered to be the main engine for the adoption of the BIM. As the same as Omer, H., (2015) s' result.

Furthermore, as illustrated in figure 8 the most source for BIM experience gained from the university stage. Whereas more than 22% believe that the designer is the main engine to adopt and convince others about the benefits of BIM as part of construction projects in Syria. This is also found in global research where there is a possibility to solve more building problems, avoid redesign and reduce change orders, which are the main factors that lead to the failure of projects to reach their goals within the cost and time set since the beginning of work (Omer, H., 2015, Elhendawi, A., 2018).

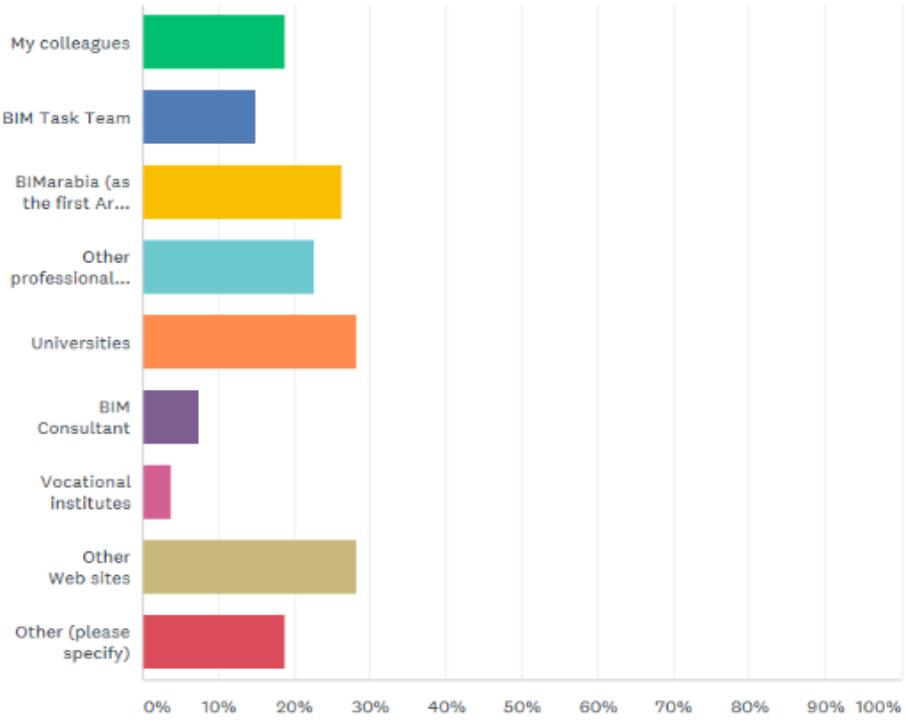

Figure 8: the most commonly used sources of experience in the field of BIM

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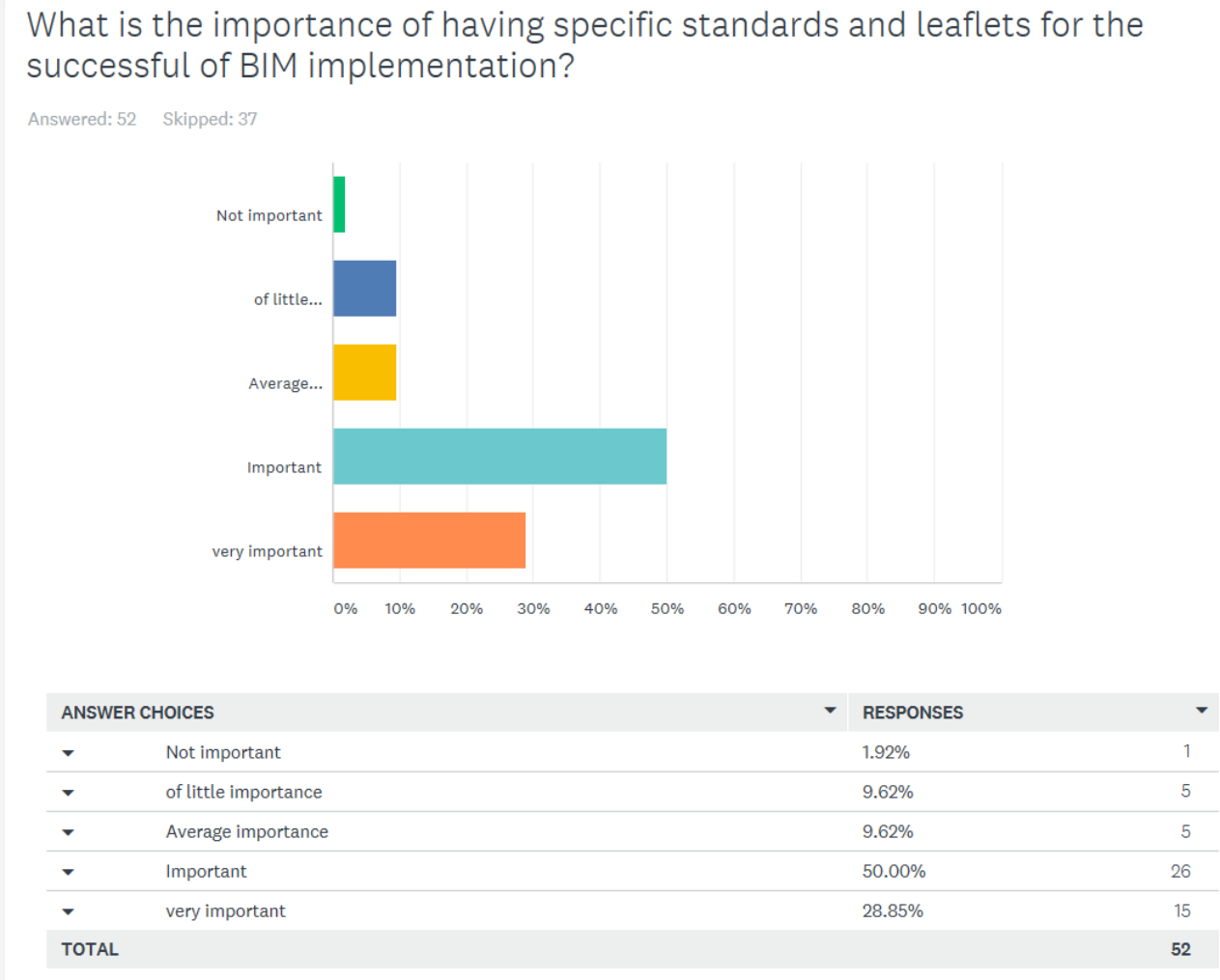
The majority of respondents 50% argued that setting a special standard to deal with the principles and techniques of BIM is important, While 29% find it is very important as shown in figure 9. This result is in line with what Omer, H., (2015) claimed.


What is the importance of having specific standards and leaflets for the successful of BIM implementation?
Answered: 52 Skipped: 37
Not important
of little...
Average...
Important
very important
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

ANSWER CHOICES	RESPONSES	
Not important	1.92%	1
of little importance	9.62%	5
Average importance	9.62%	5
Important	50.00%	26
very important	28.85%	15
TOTAL		52

Figure 9: important of existing standards for the use of building information Modelling (BIM)

The respondents mentioned the most important risks that may face the projects that will be implemented using the BIM as follows (figure 10):

- Risks of lack of clarity (unclear specifications, customer requirements, required quality of achievements).
- Misappropriation of information and consequential errors in construction works.
- The 3D models and their 2D exports have not been updated due to lack of cooperation between the parties to the project.

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ANSWER CHOICES	RESPONSES	
Risk of lack of clarity (unclear specifications, customer requirements, required quality of performance).	45.28%	24
There is no evidence to support supply chain experiences in the BIM project and the suitability of these expertise with project requirements.	28.30%	15
Not to update the 3D models and their 2D exports due to lack of cooperation between the parties of the project.	37.74%	20
Wrong transmission of the information and consequently errors of construction work on the site.	39.62%	21
Accidents and inaccuracies of technology (software, scanners, cloud points ...)	20.75%	11
Risk of non-compliance with contract terms such as payments, quality, and time.	30.19%	16
inaccuracy in information provided by gifts and tenders such as estimating quantities and costs.	20.75%	11
Delay in schedules.	13.21%	7
Total Respondents: 53		

Figure 10: Main risks facing projects implemented using BIM

This result is in line with what Elhendawi, A., (2018) concluded.

The respondents mentioned the most important factors influencing the localization of BIM as illustrates in Figure (11) as follows:

- Raising the awareness of the importance of cooperation culture between different parties
- Government policy to make the use of BIM technology mandatory through the development of special laws
- Establish an educational base for BIM technology by making it part of the curricula of universities
- Providing government support for the implementation of BIM technology in private companies and institutions
- Allocate financial funding to support the costs of BIM technology
- Engaging with international specialists with expertise in BIM technology
- Development of contracts and legal materials governing the use of BIM technology.

This result is in line with what Elhendawi, A., (2018) and Omer, H., (2015) claimed.

The proposed Framework (Figure 12) was developed dependent on the extensive literature review, and the recognized three fields of BIM and the results from the questionnaire survey analysis.

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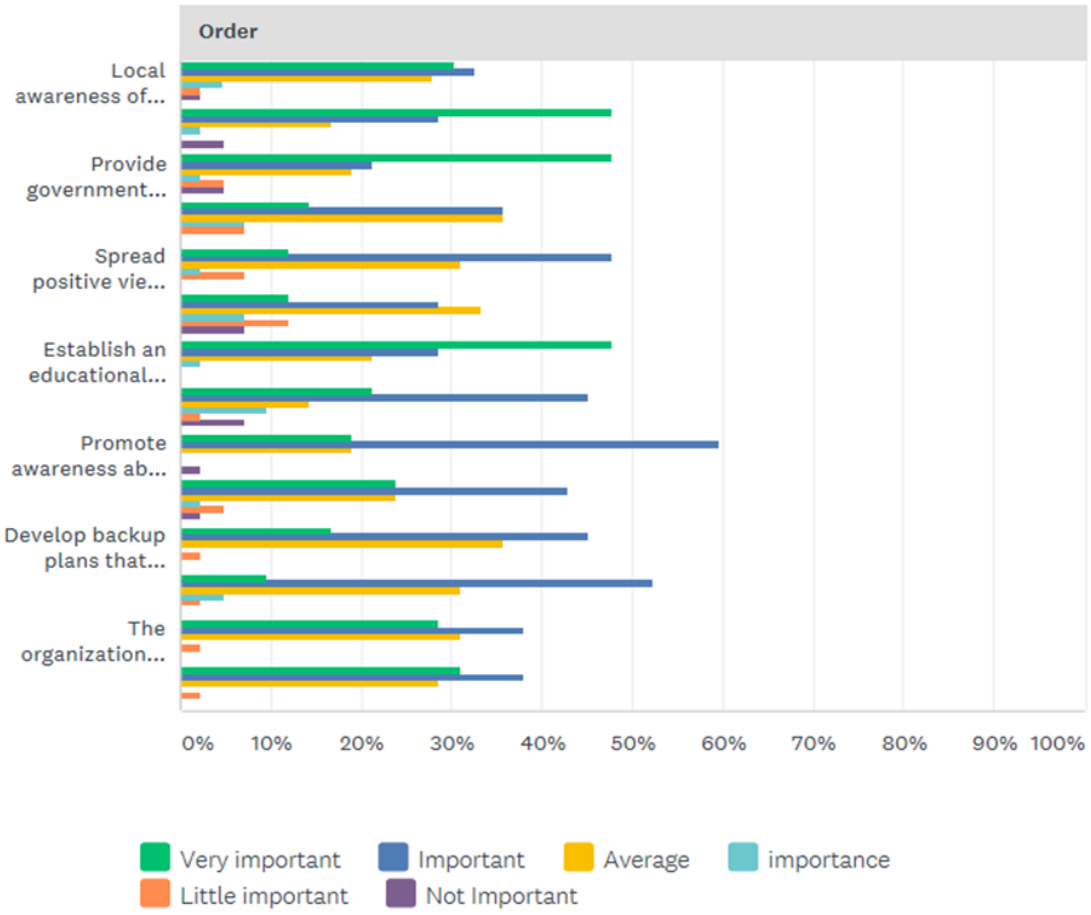

Figure 11: the most important factors help in the localization of BIM in Syrian construction projects.

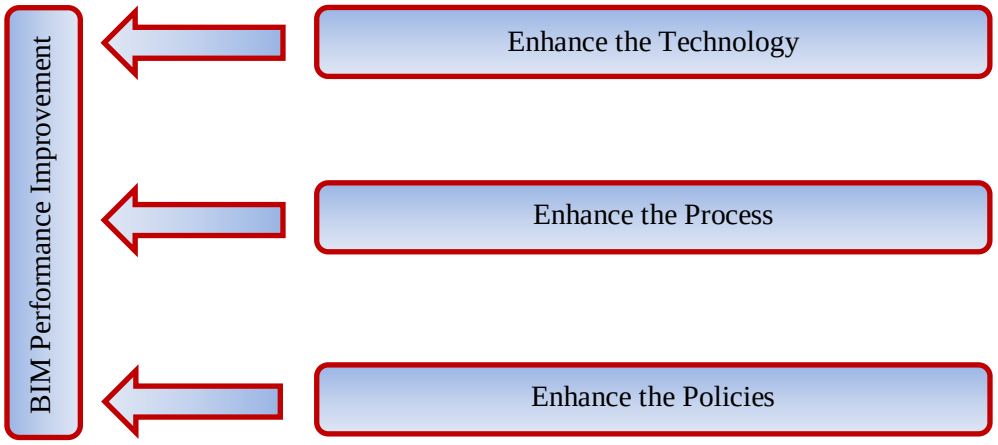

Figure 12: the proposed Framework.

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Case study (Framework Validation):

BIM Performance Measurement in the GCEC Company

The validation of the proposed framework is conducted by observing the BIM performance measurement in the GCEC Company through the fields of BIM.

Technology

- *Software*: *(applications, deliveries, and data):* Company has achieved column b (specific) in addition to attaining one aspect of cell c; the final value is 11 out of 40. In this case, with cells with lower values, these cells have a priority in working to improve them. All cells must have this optimization. Therefore, to move the software in the company to the column (the subsequent cell) (orbit) entirely and also towards the integration and optimization as much as possible, for example:
  - Setting strategic goals for the company and based on which programs are selected and managed
  - Enable interoperability of various applications by proposing formats such as IFC, which helps to use, store, share and maintain data as part of the overall strategy of the company.
- *Devices*: *(equipment, delivery, location/roaming):* The assessment has the result 0. Therefore the hardware is not suitable for the process of BIM, so:
  - Buying appropriate equipment for Building Information Modelling, and purchase workstation equipment that can be cheap or used but with good specifications (gradual change).
  - Convince the management that the replacement and promotion of equipment is an investment.
  - Standardization of hardware specifications within at least one team.
- *Network: (Solutions, Delivery, and Security/Access Control):* its assessment value was 0; which means that the network mode is not useful, you must look for the reasons.
  - It must secure the network and its solutions to ensure that information is shared between teams within a single organization and between organizations working together.
  - Solutions can replace with innovations that are regularly tested and evaluated, such as: Ensuring proper bandwidths that allow storage and exchange of data and knowledge
  - The allocation of project portals that allow for the exchange of significant data and make it interchangeable between the stakeholders in the project, leading to the participation of different parties and this reflected in improving the process and development of communication channels.

Process

- *Resources (infrastructure, physical and precognition):* The assessment has the value of 5, the Company's employees consider that the work environment and workplace tools directly affect employee motivation and productivity. So:
  - Control this environment and secure the appropriate work tools and work on the management and integration, which achieves the company's performance strategies.
  - Monitor the work environment regularly to suit the requirements of its employees and contribute to their ability to more work and productivity.

  - There is also poverty in the way of exchange and sharing of knowledge. Also recommended using specific standards and shared data environment (like CDM) and commitment which will stimulate employees and increase productivity.

- *Activities and Workflow (Knowledge, experiences and related dynamism):* The value is 10 out of 40 as illustrated above. There is good knowledge of an essential section of the company's members about BIM and its benefits and the need to apply it. So that:
  - A BIM team should be formed, the roles of all participants should be defined, and the technology should be introduced into a small pilot project and then they become essential in the company work.
  - Create a spirit of cooperation and provide the necessary communication tools within the working group and within the organization in general.
  - Gradually replace the traditional teams with newly trained teams. Or training the existing teams gradually so that the transition doesn't cause any defect or delay in the work of the company.

- *Products and services: (specification, differentiation, research, and development):* Based on the answers of the company engineers, it took value 10.
  - The company recognizes that it uses a unique statement to define the specifications and characteristics of the components of the 3D model, but there is no individual standard (such as an integrated BIM model which serves as a reference model for mensuration) can be consulted indicating the specifications to be achieved if the model is submitted.
  - To reach a product with high specifications; must specify the specifications for the progress of the model and control the product in the desired stages of development.
  - Adopt a national or international code.

- *Leadership and management: (organizational, strategic, managerial, communication, invention, and innovation)*: The rating is 0,
  - The first important step is to persuade the management to move to the BIM and provide all the supporting factors.
  - Cooperate with the supplier and develop a method to deal with him.

Policies

- *Preparation: Research, educational/training, and delivery programs*. It came in a specific box and took the assessment 10 out of 40
  - Training should be adopted on an ongoing basis and not when necessary
  - Set specific strategic objectives, so that the training fructifies.
  - MEP needs special attention. If the architectural and structural specialist had followed the REVIT and MEP engineer followed the AutoCAD program, the company would not be working on the second level of the BIM.
  - Developing a time plan.
  - Involve all parties, even those who do not work with BIM, like Quality management, and Planning.
  - Innovation strategy.

- *Organization: Blogs, regulations, legislation, classifications, guidelines, and standards*, The rating is 0
  - This study recommends the adoption of reliable codes such as British code.
  - Evaluation for each project, is the code used for this situation?
  - Need the guidance for the best methods of learning and training.

- Regarding the course, is it better to be: some long hours taught at home or class in the company.
- The development of unique records containing reports: take advantages of the recording mistakes.
- Contractual: Responsibilities, Remunerations and Risk Allocations: Also took rating 0.
- Must be done before sitting with the client and agreeing with him on the work plan.
- Method of dealing with contracts such as CIC BIM may propose to use in work within the BIM projects.

- As a result of assessing the selected company, it seems that it is approaching the level 1 of the BIM, where the engineers use some of the BIM tools as Revit architectural, and structural. In addition to the belief of the company's employees in cooperative work, which is a basic principle of the BIM. It was agreed to form the company's 6-person BIM team initially, who undertook to train others to reach an integrated team. Growing day by day.
- The selected BIM team decided to select a medium-sized project with a long and deferred time schedule to operate as a pilot project and to record this experience, benefits, and constraints in order to gradually move the company towards the BIM.
- This move will be the first in the Syrian public sector companies, and maybe an incentive to compete with other companies.

BIM performance improvement

Performance measurement is the first step to improve and manage the performance. This study provides some recommendations for every BIM areas and internal areas as shown in “Figure 13”. These results are in the line with the literature (Jung, Y. and Joo, M., 2011, Koucha, A.M., et al., 2018).

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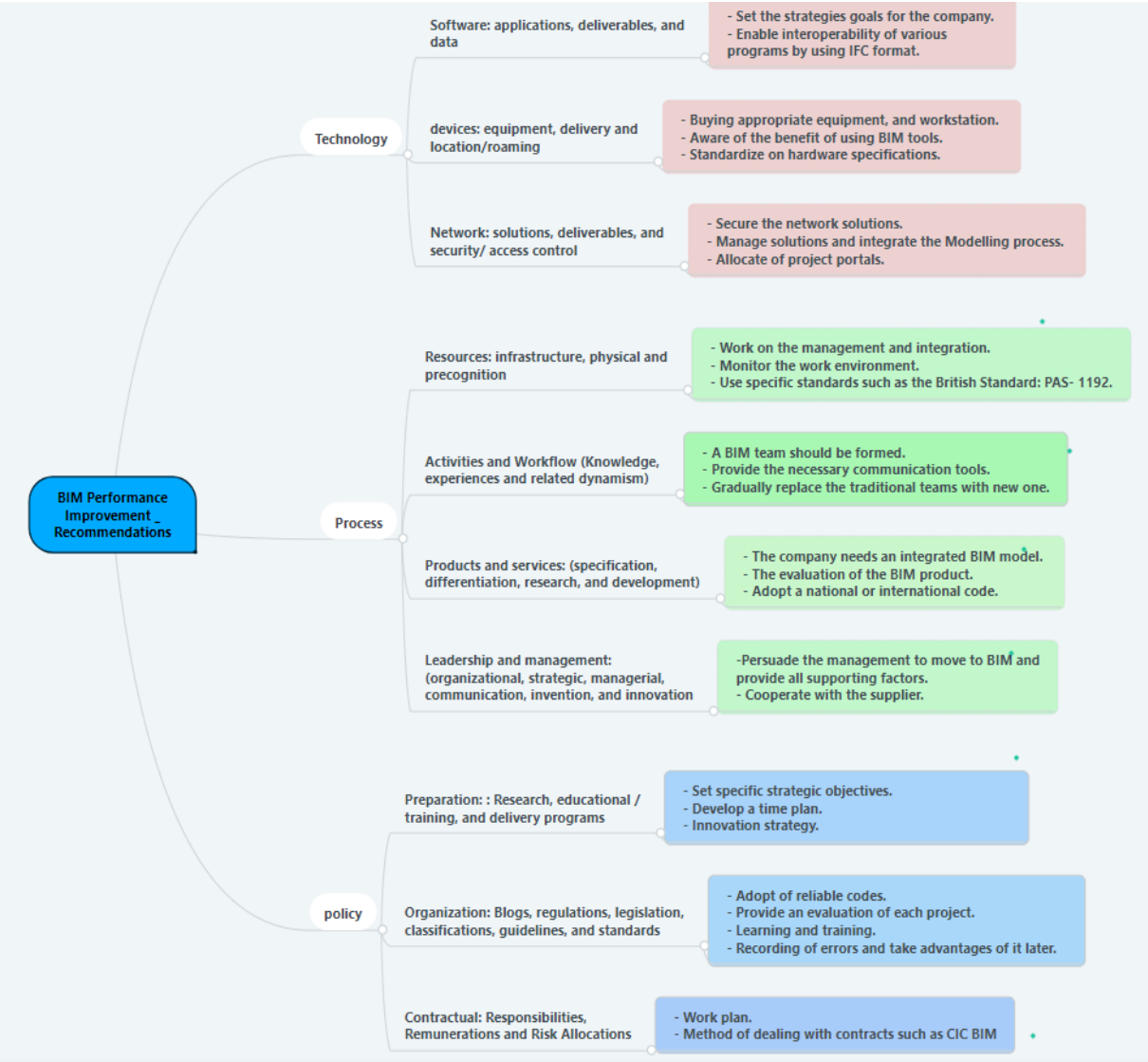
BIM Performance Improvement _ Recommendations
Technology
Software: applications, deliverables, and data
- Set the strategies goals for the company.
- Enable interoperability of various programs by using IFC format.
devices: equipment, delivery and location/roaming
- Buying appropriate equipment, and workstation.
- Aware of the benefit of using BIM tools.
- Standardize on hardware specifications.
Network: solutions, deliverables, and security/ access control
- Secure the network solutions.
- Manage solutions and integrate the Modelling process.
- Allocate of project portals.
Process
Resources: infrastructure, physical and precognition
- Work on the management and integration.
- Monitor the work environment.
- Use specific standards such as the British Standard: PAS- 1192.
Activities and Workflow (Knowledge, experiences and related dynamism)
- A BIM team should be formed.
- Provide the necessary communication tools.
- Gradually replace the traditional teams with new one.
Products and services: (specification, differentiation, research, and development)
- The company needs an integrated BIM model.
- The evaluation of the BIM product.
- Adopt a national or international code.
Leadership and management: (organizational, strategic, managerial, communication, invention, and innovation
-Persuade the management to move to BIM and provide all supporting factors.
- Cooperate with the supplier.
policy
Preparation: : Research, educational / training, and delivery programs
- Set specific strategic objectives.
- Develop a time plan.
- Innovation strategy.
Organization: Blogs, regulations, legislation, classifications, guidelines, and standards
- Adopt of reliable codes.
- Provide an evaluation of each project.
- Learning and training.
- Recording of errors and take advantages of it later.
Contractual: Responsibilities, Remunerations and Risk Allocations
- Work plan.
- Method of dealing with contracts such as CIC BIM

Figure 13: The Final Proposed Framework "BIM Performance Improvement"

5. Conclusions:

However, clients usually worried about quality improvement with reduced time, and cost, contractors, and architects are interested in performance improvements to increase their profits and enhance their competitive advantages. BIM proves its capability to enhance the cooperation between all project parties. Unfortunately, BIM is not fully applied in Syrian projects in general and within the selected company as a case study.

The majority of the public administration staff in Syria don't know quite about the BIM. This research aims to BIM performance improvement in AEC industry companies in Syria. An online survey explains the BIM adopting between Syrian engineers and determined their perspectives about the main factors influencing the BIM performance improvement. Moreover, the analysis of the company performance was based on the BIM Maturity Matrix, evaluation criteria are determined by the specific needs of the various participants of the building process. This study provides a framework to enhance

the BIM performance in the AEC industry in Syria and propose strategies for raising BIM awareness. This research provides recommendations: 1) Readiness and willingness to change are necessary to further develop the application of BIM in Syria and the world, 2) An initial team of BIM set up to be trained with the provision of subsequent staff to support the first team and start to evaluate the performance and the reality of the company and work to move gradually towards BIM as a qualitative and individual step and with remarkable cooperation for public companies in Syria.

Recommendations have been made for all aspects of the so-called BIM fields of technology, processes, and policies of the organization with an aim to improve its position and pushing it towards the second level of BIM. The influencing factors related to the technology are: 1) Setting strategic goals and selecting the appropriate programs, 2) Enable interoperability of various applications by proposing formats such as IFC, which insure using, storing, sharing and maintain data as part of the overall strategy of the company, 3) Buying appropriate equipment for Building Information Modelling, and purchase workstation equipment that can be cheap or used but with good specifications, 4) Convince the management that replacing and promotion of equipment is an investment, 5) Standardization of hardware specifications within at least one team, 6) Securing the network and its solutions to ensure that information is shared between teams within a single organization and between organizations working together, 7) Innovations would be solutions regularly tested and evaluated, such as: Ensuring proper bandwidths that allow storage and exchange of data and knowledge, 8) The allocation of project portals that allow for the exchange of significant data and make it interchangeable between the stakeholders in the project, leading to the participation of different parties and this is reflected in improving the process and development of communication channels.

The influencing factors related to the process are: 1) Controlling the BIM environment and securing the appropriate work tools and working on the management and integration, which achieve the company's performance strategies. 2) Monitoring the work environment regularly to suit the requirements of the company’s employees and enhance their ability to more work and productivity, 3) Using specific standards and shared data environment (like CDM) and commitment which will encourage employees and increase productivity, 4) A BIM team should be collected, roles of all participants should be defined, and the technology should be introduced into a small pilot project and then, they become essential in the company work, 5) Creating a spirit of cooperation and providing the necessary communication tools within the working group and within the organization in general, 6) Gradual replacing of the traditional teams with newly trained teams or training the existing teams gradually so that the transition doesn't cause any defect or delay in the work of the company, 7) The company recognizes that it uses a unique statement to define the specifications and characteristics of the components of the 3D model, but there is no individual standard (such as an integrated BIM model which serves as a reference model for mensuration) can be consulted indicating the specifications to be achieved if the model is submitted, 8) Identifying the specifications for the progress of the model and controlling the product in the desired stages of development, 9) Adopting a national or international code, 10) The first important step is to persuade the management to move to the BIM and provide all the supporting factors, 11) Cooperation with the supplier and developing a method to deal with him.

The influencing factors related to the policies: 1) Training should be adopted on an ongoing basis and not when necessary, 2) Setting specific strategic objectives, so that the training fructifies, 3) Different disciplines (Architectural, Structural and MEP specialists) should use unified program, 4) Developing a time plan, 5) Involving all parties, even those who do not work with BIM, like Quality management, and Planning, 6) Innovation strategy, 7) Recommending the adoption of reliable codes such as the British code, 8) Evaluation for each project, is the code used for this situation? 9) Guidance for the

best methods of learning and training, 10) The development of unique records containing reports: take advantages of the recording mistakes, 11) Contractual, responsibilities, remunerations and risk allocations must be done before meeting the client and work plan agreement, 12) Method of dealing with contracts such as CIC BIM may propose to use in work within the BIM projects.

This study recommends selecting a medium-sized project with a long and deferred time schedule to operate as a pilot project and to record this experience, benefits, and constraints in order to gradually move the company towards the BIM.

The future researches might deal with the validation of the proposed framework in private sector companies.

Acknowledgments

This work was supported by the Grant Agency of the Czech Technical University in Prague, grant No. SGS17/121/OHK1/2T/11

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International Journal of BIM and Engineering Science

Available online at: http://bimarabia.com/IJBES/

December- 2018; Volume: 1 Issue: 1 **ISSN 2571-1075**

Building Information Modeling in Syria: Obstacles and Requirements for Implementation

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Abstract

The crucial need for innovative sophisticated, and complex Architectural, engineering, and construction (AEC) industry projects with in-depth details makes traditional methods inappropriate for the completion of projects with desired efficiency, performance and productivity. Therefore, AEC projects in Syria suffered from myriad issues such as Behind the Schedule, over budget, inferior quality, low productivity, without sustainability and more. However, Building information Modelling (BIM) proves its capability to solve these issues. The aim of this study is to identify the obstacles and the critical influencing factors for applying BIM in Syria in the AEC industry. Extensive investigation for literature review and structured online questionnaire designed to achieve the study's aim. SPSS and Excel were used to analyze the results. This study classified the obstacles related to three category: 1) Planning, Design and Auditing systems, 2) BIM System, 3) Management, Financial and Legal factors. In spite of, the government and clients play the vital role to mandate BIM, the mixed approach (top-down and bottom-up) is recommended to expedite BIM implementation. This study provides a novel contribution by identifying the main obstacles and developing new strategies for applying BIM in AEC and reconstruction which enhance projects quality, performance and efficiency.

Keywords: BIM; AEC industry; reconstruction; obstacles; Requirements for applying; project management; Syria

1. Introduction

Recently, the AEC industry witnesses a leap in its contribution to nations' economies (Banawi, A., 2017). Therefore, the AEC industry projects turn outed to be complex and over detailed in coping up with the innovative, creative, and ingenious era. The traditional methods failed to deal with those requirements result in myriad issues, so there is an urgent need for new methods. The developed countries use BIM to solve those issues reaping the benefits of implementing BIM to achieve the project participants' requirements and the clients' satisfaction (Elhendawi, A.I., 2018).

However, the traditional systems deal with each project phase and its teams separately, the main feature of BIM is the integration of the different project phases (project management life cycle) and its teams. Therefore, BIM enhances the collaboration, the coordination, homogeneity and Interoperability (the use of a single software database system) between the project parties from the same stage and the different stages (conception and initiation, definition and planning, execution,

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performance and control, and project close) (Omar, H.S., 2015). For example, the integration between the deferent teams (from the initial idea, design through construction, maintenance and operation ended to demolition phase) reduce the design errors, save time and money, enhance the effectiveness of facility management such as providing accurate as-built drawings to facilitate maintenance and operation and so on (Azhar, S., et al., 2015).

In spite of, the traditional system concentrated in three-dimensional (3D) from different disciplines (architectural structural Mechanical and electrical power (MEP) engineers) separately, BIM coordinate those models into one model and adding more 'dimensions' of data to the information models the time (4D), cost (5D), sustainability 6D, and Operation and maintenance/Facility Management (FM) 7D model (McPartland, R., 2017).

The importance of study stems from the necessity of developing methods used in AEC industry project lifecycle in Syria to keep up with what is currently being applied in different countries of the world. To overcome the problems of the current projects and exploit the benefits of new methods. Currently, we are on the threshold of the reconstruction phase "Rebuild Syria". While the most projects suffering from over budgets, behind the schedule, and low quality (Shaban, M., 2017). BIM is widely expanded worldwide in the AEC industry, however in our Arab region including Syria, it is in its first stage (Omar, H.S., 2015). Therefore, the aim of this study is to identify the constraints and requirements of applying the BIM system in the Syrian AEC industry. In addition to determine the best stage for the application of this technology as a first stage before the full application especially in the reconstruction phase.

2. Literature Review:

Overview:

The reality of Syrian Construction Industry

The delay of the projects and the excess cost have become a common feature in this age due to the increasing complexity of the modern construction industry and its multiplicity. In recent years, several studies claimed that the main causes of delays and inefficient projects management in the AEC industry are: 1) Poor or weak design, 2) lack of integration within the design team themselves, and with execution team, 3) The absence of an integrated system to facilitate coordination between project parties as a result of the weakness of the contractual legal framework (Mandhar, M. and Mandhar, M., 2013, Sanderson, S., 2013, Ahmed, S., et al., 2018).

Table (1) summarizes the most frequent reasons for delays and inefficient management in construction projects in several countries, including Syria.

Table1 : Summary of the causes of delays in projects and poor management efficiency in Syria (Shaban, M., 1998, Shaban, M., 2006, Ahmed, S., et al., 2018)

The researchers	*Delays and inefficient management cause*
Shaban (1998), (2006)	*Many change orders* *Poor design* *poor supervision and documentation* *weakness communication and coordination between the parties to the project* *Slow decision making by supervision and other project parties* *Contract system based at the lowest price* *Failure to apply modern project management methodologies* *The contract system is incomplete / There is no design contract and another for supervision* *There is no clear methodology for the supervisory function*
Ahmad, Dlask, Shaban, Selim (2018) Mia, Hassan, Omran,	*Change orders by the owner* *Planning and scheduling problems* *Cash flow delay by the owner* *Cost estimates and inaccurate time*

Varnes (2008)	*Weak site management* *Poor communication between project team members* *Weak contract management* *Poor technical performance* *Unclear scope of work*

From table (1) and through the study of the reality of the Syrian construction industry, we find that they are characterized by the following:

1. Poor design and integration lead to significant changes in the design by all parties during the execution phase.
2. The widespread use of the tender system on the basis of the lower price, in addition to the many change orders, has become a source of concern and failure for many construction projects. The conflicts are increasing and there are a lot of aggressive attitudes towards the parties of the project and increasing the cost in the project contracts. The traditional bidding system is design-bid-build paradigm and the bad application. The system may be better designed, but the best alternative is the Integrated Project Delivery (IPD) in which all parties to the project share the risks of design and execution together, each according to their contribution to it, and share the increased productivity and good results of the project's success. The IPD system can work well if the project using a precise and accurate BIM system (Eastman, C., et al., 2009, Sacks, R., et al., 2010).
3. The productivity of the construction industry has not improved during the past 40 years, compared with other productive sectors, which increased by 200% except for agriculture (Matarneh, R. and Hamed, S., 2017).

4. The complexity of buildings and projects generally increases and takes longer to construct them, while the design duration **is** relatively short.
5. The parties to the project and its stakeholders are no longer limited to the core parties of the owner, designer / supervisor and contractor, but new parties such as the supplier, the insurer, the financier and subcontractors, the end user, professional associations and other local and government departments - environment and others who also affect the project (Mandhar, M. and Mandhar, M., 2013, Ahmed, S., et al., 2018).

6. The problem of delaying supplies to the project and coordination between the subcontractors for not being in the project management system except in later stages.

7. Waste in project resources due to the rework of defective works or to correct design defects. The key to achieving this is the transition to the BIM system, which aims to have clear design information as a common knowledge resource for all practical participants' construction as a whole, reducing the need to re-search and obtain information or to reformat and formulate this information to a specific party.

Most of the above problems will eliminated or ended if the BIM system is fully applied, but this transition is very challenging and requires a major change in the work mentality and in the construction industry systems in all its aspects. This study will attempt to explore the challenges of implementing the BIM system in the Syrian construction industry and its applicability in different stages of the project and its prospects for the reconstruction phase.

Building Information Moudling:

Michael, R. et al. (2012) reported that Building Information Modeling (BIM) is a "*digital set of adopted software applications to facilitate coordination and project collaboration between all project/construction partners*.". Whereas Teicholz, P.M., (2013) claimed that "*It is a multidimensional model (3D, 4D[time]and 5D [cost]) in which it is possible, by default, to link or*

International Journal of BIM and Engineering Science

Available online at: http://bimarabia.com/IJBES/

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attach an undetermined amount of information relating to the typical project elements / construct as a set of characteristics both visible and invisible.". Furthermore, Barrinton, S. (2010). argued that "*BIM is a digital representation of the physical and functional characteristics of a building or project, and is a shared knowledge resource for information about the formation of origin and a reliable decision-making base throughout its entire life cycle from the beginning/idea and later to the end of the planned life of the project*. "

The BIM is used to describe an advanced technology for 3D CAD design for modeling and managing buildings and related information. The BIM models of traditional CAD models demonstrate that the software models in the BIM models are clear to the software as image / Or as a reflection of the actual building components, unlike the graphics models in the two-dimensional computer design files " (Sacks, R., et al., 2010).

Moreover, the American Institute of Architects (AIA) defines the BIM as a "*model-based technology model linked to the database of project information." In the Encyclopedia of Engineering, Wikipedia states that the BIM system includes engineering dimensions, spatial relations, the geographic information, the quantities and properties of the components of the building/project properties*" (Breen, G., 2018).

The basic idea of the BIM system is the collaboration, see Figure 1, between project stakeholders throughout the project life cycle to insert, extract, update, or modify information in the BIM processes to support and highlight project roles (NBIMS Project Committee, 2008).

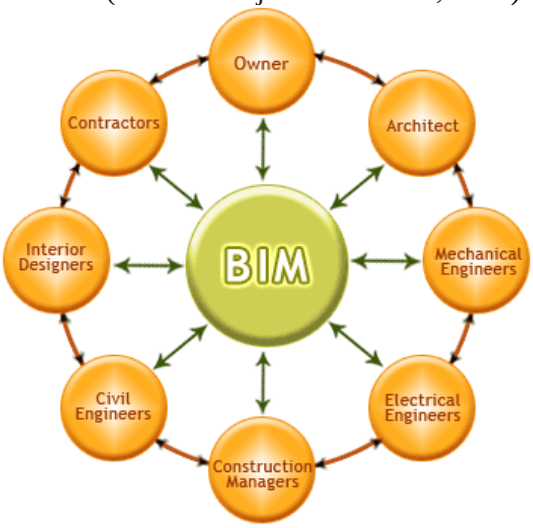

Figure 14 Relations /Collaboration between the parties to the project [43]

The BIM system has been found to be the basis for solving problems and errors resulting from the fragmentation of a project / building system - splitting the process of designing and establishing the project into separate phases - or managing all the information we need in a specific project to be combined with a single repository accessible / Source of information) by all participants, and the ease of integrating all project documents (NBIMS Project Committee, 2008). Figure 1 shows how each project party or stakeholders can access directly the project's shared database, and modify the necessary documentation and incorporate it into the database to make it accessible to all. By looking at above figure we find that the BIM system is characterized by the following (Liu, R., et al., 2010, Shaban, M., 2017).

1. Less paperwork considering that information exchange is fully electronic

2. Provide the latest information for everyone.
3. Provide a complete record/ register of the project
4. A full review of all project information.
5. A single database of project information rather than "isolated islands/silos".
6. Great potential for reuse of information in the operation and maintenance phase.

Thus, the BIM system provides the opportunity to speed up processes that were usually executed sequentially. In addition to that, BIM allow us to perform some activities simultaneously or parallel – e.g. synchronization of design processes with execution and execution with operation. BIM proves its capability to reduce project time and increasing profits (Omar, H.S., 2015, Elhendawi, A.I., 2018).

The United States is the first country to implement the BIM system, the General Services Administration (GSA) has printed the BIM Manual Series, the National 3D-4D-BIM Program and its applications in more than 35 projects (Eastman, C., et al., 2009), And the US Army Corps of Engineers has developed a plan for the full implementation of this system on all projects in 2012 at the latest. In July 2010, the Pennsylvania State University (PSU) developed the BIM Implementation Plan, which was the result of the so-called building SMART Alliance Project, in which it was suggested that the level of detail/development in the LOD should be described in addition to the standard data structure in order to effectively manage the project (Eastman, C., et al., 2009, The BIM Hub, 2014, Banawi, A., 2017). In Britain, in May 2011, the Prime Minister's Office printed the Government's Construction Strategy, in which he announced that he would coordinate government efforts among various stakeholders to enable them all to cooperate effectively through the BIM system. In Hong Kong since 2006, the BIM system has been implemented in more than 19 public housing projects in the design and implementation stages. The Hong Kong Housing Authority (HA) developed their own in-house BIM standards and user guide for both the architect and the rest of the design team engineers for the proper use of the BIM system during the design phase. Hong Kong established the BIM Institute of BIM and special conferences are held each year (Eastman, C., et al., 2009, Banawi, A., 2017). There are many studies around the world that have been subjected to the application of the BIM system in the construction industry for example (Liu, R., et al., 2010, Kiani, I., et al., 2015).

Obstacles hinder BIM implementation:

Banawi, A.,(2017) summarized the main obstacles to applying BIM as: 1) The market is not ready, 2) the clients do not demand BIM , 3) Training Costs and the learning curve are too high, 4) The difficulty of having everyone on board to make BIM effort worthwhile, 5) Too many legal barriers exit and they are too costly to overcome, 6) Issues of model ownership and management will be too demanding on owner resources, 7) Designers or Architectural Engineering firms do not usually prove empirically the benefits of BIM to customer, 8) Construction Insurance companies do not have BIM projects risk specific policies, 9) Technology risk and barriers technology is ready for single-discipline design but not integrated design, 10) BIM is not having a full support of upper management or decision makers.

However, Matarneh, R. and Hamed, S., (2017) summarized them as:1) Lack of support and incentives from construction policy makers, 2) standards and codes are not available, 3) Lack of awareness about BIM, 4) No client demand. 5) Resistance of change, 6) Lack of a BIM specialist, 7) Necessary training is not available, 8) Cost (software, hardware upgrade, training, and time), 9) BIM requires radical changes in our workflow, practices and procedures.

Whereas Omer, (2015) categorized the main obstacles in to five groups as follows:

1. Management obstacles
2. Technical obstacles

3. Surrounding environment obstacles
4. Financial obstacles
5. Legal/contractual obstacles

Furthermore, as a result of extensive investigation for the literature review the key obstacles are shown in (table 2).

Table 2: Key obstacles that impede BIM implementation

Ser.	Obstacles for applying BIM
Management obstacles	
1	Inadequate BIM experience (know-how) to change [3,22].
2	Inadequate support from the top managements to adopt BIM [5,6,41,56,57].
3	Resistance to change [17,21,47,57]
4	Difficulties correlated to workflow transition due to changes in roles and responsibilities [21,33]
Technical obstacles	
1	Inefficient Interoperability [14,16,39]
2	Difficulties of managing BIM Model [13,18,24]
3	Lack of skilled resources and complexity of BIM software [17,28,30,31,39]
Surrounding environment	
1	Lack of demand from the governments/clients to use BIM [13,15,17,29,56]
2	Not all stakeholders are using BIM [18,31,39]
Financial obstacles	
1	Costs associated with the implementation of BIM [14,16,17]
Legal/contractual obstacles	
1	Unclear Intellectual Property Rights (IPR) [6,21,28,47]
2	AEC Traditional procurement methodology [24,33,47]

BIM implementation requirement:

Kiani, I. et al. (2015) reported the main requirement of BIM applying are: 1) Introduce BIM in university curriculums, 2) Training the staff, 3) Conceive the clients about the importance of BIM, 4) Provision of legislation of BIM usage, 5) Reducing the price of BIM software.

However, Liu, R. el al. (2010) divided the factors influencing applying BIM into two category: external forces as:1) Competitive strength, 2) Influences from other cooperating parties, 3) Influences from competitors. In additional to internal readiness as: 1) Top Management Attitude, 2) Financial Cost importance, 3) BIM training.

Whereas, several researchers and professionals argued that, the key push factor to rapid BIM implementation in the AEC industry is that the governments and clients demand strictly using BIM in their projects (Moreno, C., et al., 2013Chien, K., et al., 2014, Elmualim, A. and Gilder, J., 2014).

Furthermore, Omer (2015) argued that Surrounding environment and competitive pressure push the organization to implement BIM. Figure 2 shows the organizations attitude awards BIM

International Journal of BIM and Engineering Science

Available online at: http://bimarabia.com/IJBES/

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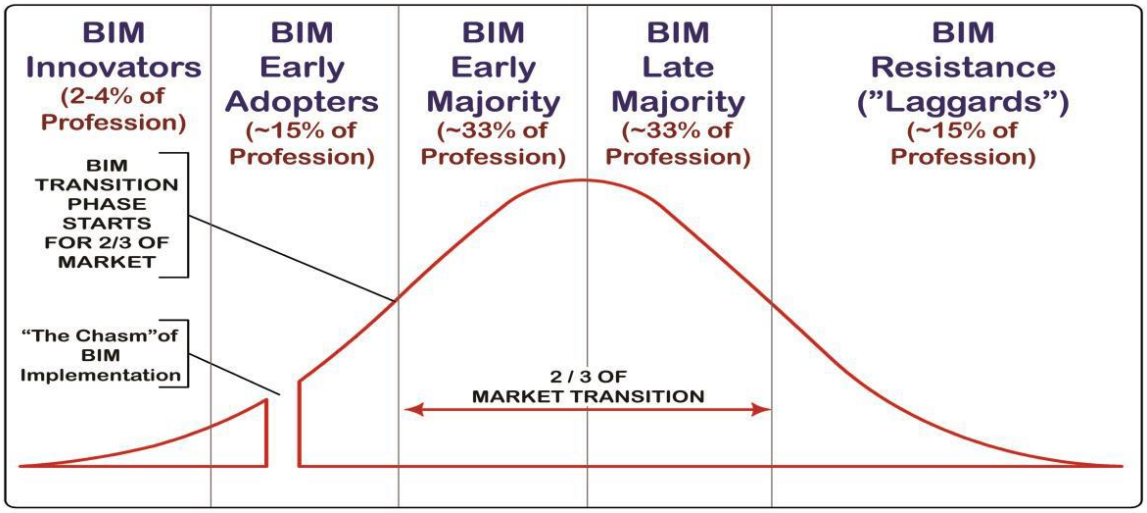
BIM Innovators (2-4% of Profession)
BIM Early Adopters (~15% of Profession)
BIM Early Majority (~33% of Profession)
BIM Late Majority (~33% of Profession)
BIM Resistance ("Laggards") (~15% of Profession)
BIM TRANSITION PHASE STARTS FOR 2/3 OF MARKET
"The Chasm"of BIM Implementation
2 / 3 OF MARKET TRANSITION

Figure 15: BIM adoption lifecycle (Moore, G., 2003).

Therefore, BIM innovators and BIM early adaptors have more competitive advantages compared to their competitors. Competitive advantages is a considerable pressure and external pushing forces for BIM non-users to adopt BIM or they will be out of the game (Liu, et al., 2010, Chan, C., 2014, Eadie, R. et al., 2014).

Moreover, Projects complexity and profit declination is considered one of the main factors push the BIM adoption. While, the BIM implementation could be the viable solution to save the waste of time and its relevant issues. Furthermore, BIM implementation offers a viable advantage to overcome the reduction of productivity problems (Eadie, R. et al., 2014, Elmualim, A. and Gilder, J., 2014, Azhar, S., et al., 2015).

Therefore, the main factors influencing the BIM adoption can by derived from how to overcoming the stipulated obstacles for applying BIM above as shown in table 3:

Table 3: Overcoming the Obstacles for applying BIM

Ser.	Obstacles for applying BIM	Removing the Obstacles
	Management obstacles	
1	Inadequate BIM experience (know-how) to change	- Introduce BIM in university curriculums (Long term) and Training the staff (short term) (Kiani, I., et al., 2015, Omar, H.S., 2015).
2	Inadequate support from the top managements to adopt BIM	- Top management should be convinced to support this change to take the decision of making BIM as obligatory (Linderoth, H., 2010).
3	Resistance to change	- The successful change can be established through two steps: Understanding the need for change and recognizing the benefits than getting ready for the change which involves the people, processes, and technology (Kotter, J. & Schlesinger, L., 1989). - Bottom-up and top-down approaches should be adopted concurrently (Arayici, Y. et al., 2011). - Applying successful strategies for change management to eliminate any potential change resistance (Arayici, Y. et al., 2011, Eastman, C., et al., 2011).
4	Difficulties correlated to workflow transition due to changes in roles and responsibilities	There is a crucial need to change from the traditional to an integrated procurement strategy, which requires a paradigm shift of mindset to accept the changes and reshaping roles and responsibilities, sharing the risks and rewards among the construction players (Sebastian, R., 2011, Haddad, G, , 2014, Love, P. et al., 2014).

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Technical obstacles		
1	Inefficient Interoperability	IFC schemes can overcome the conflicts that may appear of using different software of BIM models (Liu, R., et al., 2010, Eastman, C., et al., 2011, Ku, K. and Taiebat, M., 2011).
2	Difficulties of managing BIM Model	Assigning a model manager or as called BIM manager is essential to eliminate the BIM model-related risks who is authorized to edit data for the master federated BIM model (Thompson, D. and Miner, R., 2007).
3	Lack of skilled resources and complexity of BIM software	For the sake of providing the market with BIM skilled resources, governments support AEC university students' curriculum with integrated guidelines for BIM training programs in addition to the help of BIM software vendors to enable the trainees to keep up with the latest BIM skills in the shortest time (Azhar, . S., 2011, Chan, C., 2014, Gu, N. and London, K., 2010).
Surrounding environment		
1	Lack of demand from the governments/clients to use BIM	Conceive governments and clients about the importance of BIM (Elhendawi, A.I., 2018, Kiani, I., et al., 2015, Omar, H.S., 2015).
2	Not all stakeholders are using BIM	Governments and clients mandate BIM and Conceive BIM non-user about BIM benefits (Elhendawi, A.I., 2018).
Financial obstacles		
1	Costs associated with the implementation of BIM	Governments should providing training programs to educate organizations' staff on how to implement and use BIM and offer awareness sessions through professional institutes and academia to promote the organizations' awareness of the significance and benefits of BIM, to encourage them for investing in BIM." (Chan, C., 2014). Government should collaborate with software vendors to make training programs (Hore, A., 2006).
Legal/contractual obstacles		
1	Unclear Intellectual Property Rights (IPR)	Several professional executives and researchers reported that the IPR detailed with responsibilities and rights of all parties and level of data transfer (LOD) should be submitted in a contract document by the government in standard document or by the client (Gu, N. and London, K., 2010).
2	AEC Traditional procurement methodology	IPD was proposed to be the appropriate construction procurement strategy suitable for BIM, where IPD is defined as a "project delivery approach that integrates people, system, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to optimize project results, increase value of owner, reduce waste, and maximize efficiency through phases of design, fabrication and construction" (AGC, 2010).

There are few studies that have dealt with the obstacles to applying the BIM system in Syria. Some studies focused on the benefits of application, especially in the design stage. This is due to the absence of actual and complete application of the BIM system in the Syrian construction industry. The application of this system systematically, and in the absence of controls or manual as used in the countries that began to apply it, in the study (Haddad, G, 2014) found the usefulness of applying the BIM in the design phase in terms of cost and time to obtain design documents compared to With the traditional CAD system In this study, the researcher investigated the effect of change orders in the design documents and the levels or results of this change on the whole project using the BIM system. Developed a software method within the Rivet program to track the impact of change orders in the project. The study (Ahmed et al, 2018) dealt with the possibility of applying BIM within the Syrian construction projects and concluded a series of economic, technical, organizational and human challenges facing the application of BIM in construction projects Syria. There are some studies that dealt with other aspects of the application of BIM in the Syrian construction industry. However, these studies did not address the obstacles to applying BIM in the Syrian construction industry and the changes that must be made in advance. The opportunity is great now, especially as we are on the

threshold of the beginning of the reconstruction phase to bring about a significant change in the Syrian construction industry through the application of modern technologies, including the BIM system, which is discussed in this research.

3. Research Methodology

Data collection

The first stage is an extensive investigation for literature review was conducted to make a clear understanding of the key barriers and main influence factors to BIM implementation. Whereas, **the second stag**e is a questionnaire was designed to collect information from the construction industry (in Syria) in the public and private sectors as well as academics in Damascus and Homs in 2017 between February and August. The survey was prepared by pilot study through preliminary interviews where ten initial active/structural interviews were conducted with professionals involved in reconstruction projects in various stages from planners, designers, contractors, and supervisors to identify the main obstacles to the implementation of the application and the prospects for its implementation in the reconstruction phase. The questionnaire consists of three main parts:

1. Introduction to research and its purpose.
2. General information about respondents, such as position job title, experience, type of entity, public sector or private organization, experience in the BIM system.
3. A table containing the main obstacles / main factors of the challenges of application of BIM in the Syrian construction industry obtained from the previous studies and from the active interviews and those identified by the researcher based on his experience, and it enumerate (25) factors, which are distributed to three groups (Table 4) :

(A) Set of factors/obstacles related to planning, design, and auditing (1 to 9);
(B) Set of factors related to the BIM system itself (10 to 17);
(C) Administrative, financial and legal factors (18 to 25);

Respondents were asked to determine the degree of importance for each worker/obstacle using Likert scale (Very High, High, Medium, Low, and very Low) based on own experience in the field of design, implementation and project management in general and in the field of special use and applicability in local Syrian conditions, particularly in reconstruction projects etc., In addition, respondents were asked to add any factor not included in the table with its importance. A total of 90 questionnaires were distributed to various stakeholders in the construction projects in Syria by e-mail and direct hand delivery. Seventy-six forms were received or retrieved, and four forms were rejected for lack of validity, accordingly, the data were analyzed from 72 completed forms in this study, however the sampling size are 100.

Data Presentation and Analysis

Respondents' Profile:

The data were dumped, sorted and then analyzed using statistical methods using Excel and SPSS software. Table (4) provides information on the management or organization in which the respondent operates in terms of type, size, and scope of work. Slightly more than half of the sample works in the government sector and is the primary concern of the construction industry, its overall development and the management of reconstruction program projects. The information also shows that 37.3% of the business organizations or departments in which the respondents work are engaged in the field of design and supervision, and 50.4% work in the field of implementation and project management in general.

There is 5.6% for regional planning and real estate development and 6.7% for training and education. Therefore, we will need to qualify technical and administrative workforce /staff for the application of

BIM. This means that the sample is balanced in terms of structure to include all categories and entities that are directly related to the construction industry and the application of the BIM system.

Table 4: General information about the respondent organization

Type of organization	**Ratio%**
Public sector	52.6
Private sector	47.4
Organization size/number of employees	**Ratio%**
0-10	41.7
10-50	27.8
50-100	13.9
100- 200	9.7
more than 200	6.9
Type of organization	**Ratio%**
Buildings execution	20.8
Infrastructure execution	15.7
Supervision and designs	37.3
Project management	13.9
Regional planning and real estate development	5.6
Education / Training	6.7

Table 5: General information about the respondent's work

Responder's specialization	**Ratio %**
Execution Engineer	23.6
Design / supervision consultant	36.6
Project Management (Heads of sections + Project Managers)	20.0
Academic Education / Research / Training	12.5
Professional departments (Engineers Syndicate ....)	7.3
Years of experience (in construction)	**Ratio %**
0-5	18.1
6-10	27.8
11-20	23.6
more than 20	30.6
Experience in the application of BIM(years)	**Ratio %**
no experience	40.2
1-2	27.8
3-5	18.1
5-7	8.3
more than 7	5.6

Table (5) shows information about the respondent's work, in which 80.2% works directly in the construction industry, 19.8% is related to this industry in one form or another. Universities and research centers play an important role in the implementation of BIM research, especially for the role of the various training institutions in qualifying the necessary human labor, especially in light of the

migration of a lot of technical staff and skilled HR and well-qualified workers during the past years due to lack of security and lack of job opportunities.

Since the experience in the field of BIM is poor among the workers in the construction industry - as the sample shows, despite its weak or individual application in some projects by some consulting offices, it is not implemented as a large-scale system that needs to qualify labor and physical resources to move from the traditional system-CAD to the modern BIM system, when asked about the experience available in this field, we find that 40.2% of the respondents have little experience in this field, and the rest have different experiences and modest application of BIM, especially in the design stage.

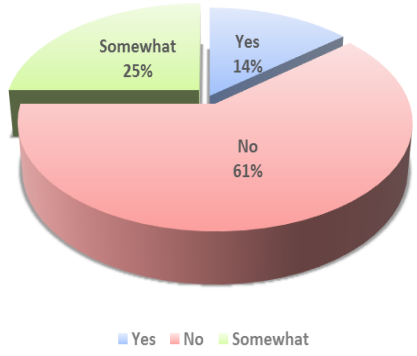

*Figure **16:** the degree of knowledge of the respondents with the BIM system*

The most of respondents (55.1%), are unaware of the importance of the BIM system and do not have the knowledge and skill to apply it at the present time due to their direct participation in projects using this system. Hence, the importance of this research to inform the decision-makers in the Syrian construction industry and the reconstruction program of the current situation of the BIM system and its importance and challenges to its application and prospects for possible implementation in construction projects in the reconstruction phase.

The answer to the question: Do you have knowledge and skill using the BIM system? The results were distributed as follows: 61% of the respondents does not have the knowledge and skill, and this actually corresponds to the obstacles or results obtained above, especially in terms of non-spread of the culture of BIM between the project parties and those concerned and the lack of adequate training for engineers and the migration of qualified personnel, 39 % Of the sample have the knowledge and skill of applying the BIM individually in the design phase only, see Figure 3.

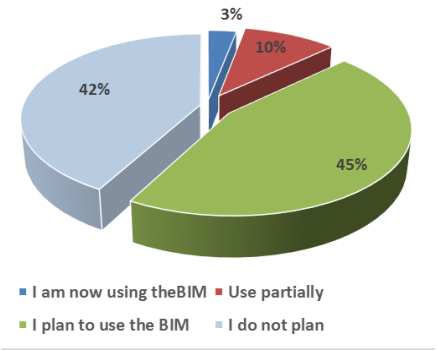

Figure 17: Prospects for the use of BIM now and in the future in the Syrian AEC industry

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As shown in figure 4, 45 % of the respondents planned to use BIM and only 13 % already use BIM, however, 42 % do not plan to use BIM. This is another confirmation to the need for convincing all the AEC industry projects participants about the BIM benefits.

4. Results and discussions:

The most of respondents (61%) argued that BIM can be applied at the design stage, as shown in Figure 5. This is confirmed by (Haddad, 2014), While 21% claimed that BIM can be applied at the design and implementation stages. This result does not with the line of what Elhendawi, 2018 and Omer, 2015 reported which they claimed that BIM can be applied in any project stage through its lifecycle. The respondents (72%) believe that BIM suitable for the reconstruction phase, as the opportunity is ready to modify the environment of the laws governing the construction sector, see Figure 6.

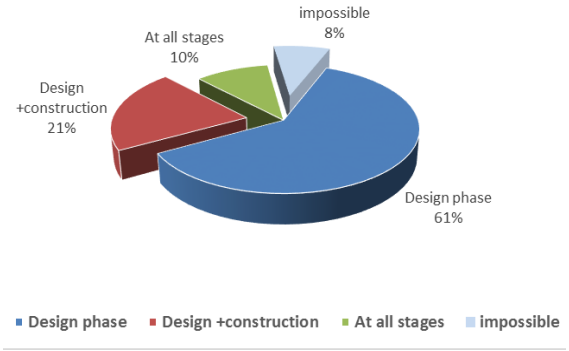

Figure 18: Preferred BIM application now

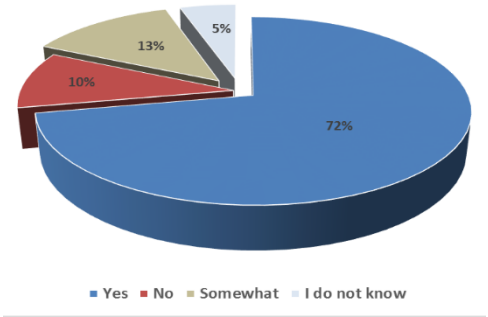

Figure 19: Appropriate application of BIM in the reconstruction phase

Reducing design document inconsistencies, ie, reducing design errors leading to change orders, which in turn lead to disputes among project parties and thus increase its cost and duration. The responses were distributed as follows: 25% and 53% felt that the BIM system could significantly reduce design defects and defects, Figure 7.

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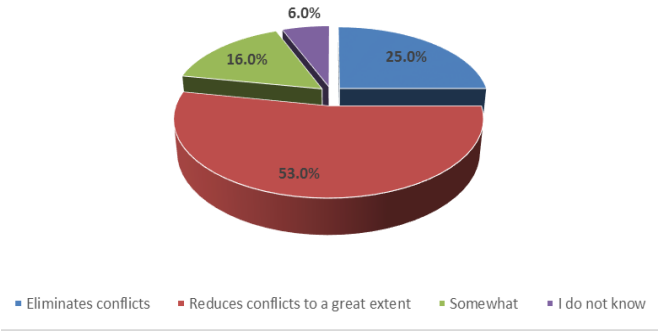

Figure 20: BIM's contribution to reducing design document inconsistencies

Obstacles of applying the BIM system in the Syrian construction industry:

Table (6) shows the factors of the obstacles and challenges of applying the BIM system in the Syrian construction industry with their importance.

The first line of columns (7,6,5,4,3) of this table shows the descriptive scale used in the questionnaire as explained above. This scale has been converted to a quantitative scale - to the degree of importance of each of the factors listed in the scale - according to the Likert scale where the number 1 means that the factor is negligent and falls to 5 and means that the factor is very important. The figures in columns (7,6,5,4,3) in Table (6) are the percentage of respondents' responses to the importance of each factor. In the eighth column, the Mean Rank value was determined to the degree of importance of the factor according to the Likert scale. In column 9, we listed the order of factors by the degree of importance. The degree of importance has been classified into areas as follows:

The degree of importance (the intensity of the effect) is distributed over an area of 5-1 = 4, and we have the degree of importance divided into five levels. Thus, the importance of each field is (4/5) 0.8, (for example low importance is from 1.00 to 1.80). From the ninth column we find that there are six very important factors / Critical factors, 12 are high important factors and 7 are moderately important factors. We did not find a weak or negligent factor and this is consistent with the effort to determine these factors from previous studies and direct interviews was conducted with some professionals in construction projects.

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Table 6: the main obstacles hinder using the BIM system in the Syrian construction industry

No.	Factor description	Negligent	Poorly important	Moderate importance	High importance	Very important	Average	Ranking
		1	2	3	4	5		
	A) A set of factors related to Planning, Design and Auditing systems							
1	Lack of clear design team	0.0	12.5	23.6	25.0	38.9	3.90	13
2	Do not specify the qualifications of the design project manager	6.9	25.0	15.3	27.8	25.0	3.39	19
3	Individualism in the design process	4.2	8.3	11.1	41.7	34.7	3.94	11
4	Formal audit / transition to audit during design implementation	6.9	23.6	26.4	22.2	20.8	3.26	24
5	The design code and its Appendixs must be modified in accordance with the BIM system	1.4	8.3	6.9	25.0	58.3	4.31	2
6	(traditional and according to the BIM system)The absence of a contract for studies and design	2.8	15.3	18.1	19.4	44.4	3.88	14
7	The absence of a unified project costing and control system at the design and excution stages	6.9	18.1	26.4	27.8	20.8	3.37	21
8	No clear and unified system to determine the owner's requirements of the in the project	8.3	18.1	16.7	41.7	16.7	3.45	18
9	Not to apply modern techniques in project management in the design and executive stage	11.1	16.7	23.6	20.8	27.8	3.38	20
	B) The set of factors related to the BIM System							
10	The weakness of the BIM culture among workers in the construction industry	1.4	5.6	8.3	22.2	62.5	4.39	1
11	Cost of software (legal licensed) and hard equipment required	12.5	11.1	13.9	18.1	44.4	3.71	16
12	Cost of training on the new system	4.2	6.9	9.7	16.7	62.5	4.26	3
13	Difficulty of change: Transport from the traditional CAD system to the BIM system	2.8	4.2	19.4	29.2	44.4	4.08	7
14	Compatibility problem between different software platforms used	0.0	8.3	22.2	36.1	33.3	3.94	10
15	The issue of creativity / intellectual property of schemes and creative ideas /	0.0	2.8	18.1	30.6	48.6	4.25	4
16	Absence of occupational engineering insurance system	11.1	13.9	30.6	20.8	23.6	3.32	23
17	Difficulty applying the BIM system in the executive stage / Lack of qualified contractors	2.8	4.2	12.5	27.8	52.8	4.24	5
	C) A set of Management, Financial and Legal factors							
18	Difficulty involving the contractor in the early stages of the project	1.4	4.2	27.8	25.0	41.7	4.01	8
19	Contractor's access to and modification of project documents during implementation	2.8	5.6	25.0	23.6	43.1	3.99	9
20	The need to modify the contracting systems in the project environment in accordance with the BIM	0.0	4.2	15.3	33.3	47.2	4.24	6
21	The need for a new, dynamic and diverse contractual environment	2.8	20.8	6.9	19.4	50.0	3.93	12
22	Procurement system or supplying/ project processing and subcontracting	16.7	20.8	19.4	26.4	16.7	3.06	25
23	Lack of transparency in the procedures accompanying the project contracts	0.0	13.9	27.8	37.5	20.8	3.65	17
24	Do not apply clear methodologies for project management and tracking	2.8	13.9	16.7	30.6	36.1	3.83	15
25	Difficulty of communication between project parties	8.3	16.7	30.6	22.2	22.2	3.33	22

Poor important Moderate High importance Very important

Critical factors/ very important factors

Returning to the ninth column, we find that the factors that are of great importance and which should be taken into consideration are mainly related to the application of the BIM system and the changes that are necessary to be made in the Syrian construction industry laws and regulations directly in the different phases of the project. Design, contract, implement and follow up the addition of factors related to training and the issue of intellectual property taking into account global developments in the field of construction contracts. The distribution of these "very important" factors is clearly shown in Figure 8, which shows the importance of these groups covering various aspects of the Syrian construction industry. "The need to modify the design code and its accessories in accordance with the BIM system" of Group A, concerning the systems of advance planning, design and auditing, emphasizes the need to modify the design code in accordance with the BIM techniques and application guide to promote the use of this technology. The consulting firms that apply this technology will not be able to compete with the offices that apply the traditional methods of design-CAD system due to the high cost of the BIM technology at this stage due to the weakness of local expertise in this field and the cost of using licensed software, knowing that this technology will provide financial savings from the total cost of the project, since it allows for good coordination and

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coherence between the design, implementation, and improvement of the via-bility of a private building and that the time available for business planning and design a few somewhat.

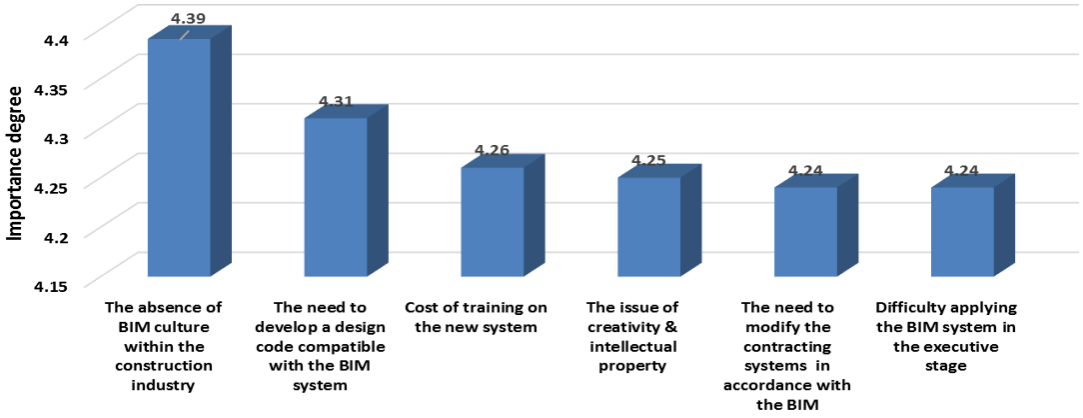

Figure 21: the very important obstacles to the application of BIM in the Syrian AEC industry

Among the group of factors related to the B-system, Group B, we have four factors, namely: "the poor of the culture and importance of the application of BIM among the workers in the construction industry." This fact is that the spread of this culture is limited to university students and new graduates, the actual application or experience in the construction industry on a limited scale. This factor obtained the largest value of the frequency ratio/rate with an average value of 4.39. The "cost of training on the new system" came in third place and this reflects the urgent need to train cadres/crews on this new technology before starting to apply it on a large scale, especially in light of the migration of expert engineering cadres during the long Syrian's crisis years. Furthermore, although there is limited training on this technology by the Engineers Syndicate and others. The fourth issue is "Intellectual property of creative designs and ideas": The issue of intellectual property or "engineering compatibility/context" is not yet in the engineering field in Syria. Engineering work, especially design, is creative. It is, therefore, necessary to develop intellectual property protection systems to include the design works of the projects as well, especially at the present time, as it is possible to easily steal and reproduce as the design today is electronic mostly, and in the fully implemented BIM system, the problem seems larger and clearer. In this case, some parts of the finished or semi-final design are electronically traded between the project parties, except for the access of the other stakeholders (from the owner, contractor, etc.) to the project database , In the past or the traditional drawing paper system, the engineer kept a transparent copy of the drawing documents "transparent drawing paper" and the owner or other cannot obtain additional copies without returning to the design engineer, which preserves his professional or intellectual rights. Currently, because of technical development, it is easy reproduction and photocopying of engineering drawings though Another decent project. Therefore, this matter is very important and requires special legislation by the supervising bodies concerned with practicing the engineering profession such as the Engineers Syndicate.

The next factor, "The difficulty of implementing the BIM system in the execution phase / lack of qualified contractors", which ranked fifth in terms of impact, reflects the inability to apply BIM now in the execution phase due to the lack of qualified contractors to deal with the BIM system, on the one hand, The implementation of current Syrian contract does not allow the contractor to interfere and change the design or access to the project database during design or contracting. Therefore, this factor is related to workers 20 and 21 on the need to modify the contracting systems so that they are diverse and dynamic to meet the requirements of reconstruction projects. Group C: Administrative, Financial and Legal Factors: Working Group No. 20: "The need to amend the contracting systems in the project environment in line with the BIM / Syrian contracting law" is a major obstacle to the wide application

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of the BIM system. There seems to be an urgent need to modify the contracting laws to keep pace with the BIM system and its environment based on its global experience and application guide in accordance with the local conditions of the Syrian construction industry.

High-level factors

Within this classification, most of the obstacles to the application of the BIM system in the Syrian construction industry are (12) factors. We will discuss the most important factors, as they fall within the three groups. See Figure (9). Design and Audit We have four factors out of nine (55.55%) with numbers (1,3,6,8). This is normal because the BIM system focuses on the effort at this important stage of the project. The design phase in the CAD traditional system is very flawed as a result of the nature of this method, where the individual character of the design and lack of cooperation and coordination between the specialist (8) "The absence of a clear and uniform system for determining the owner's requirements in the project according to the BIM system (the extent of the owner's participation in the design phase)" is particularly important if the owner does not have special

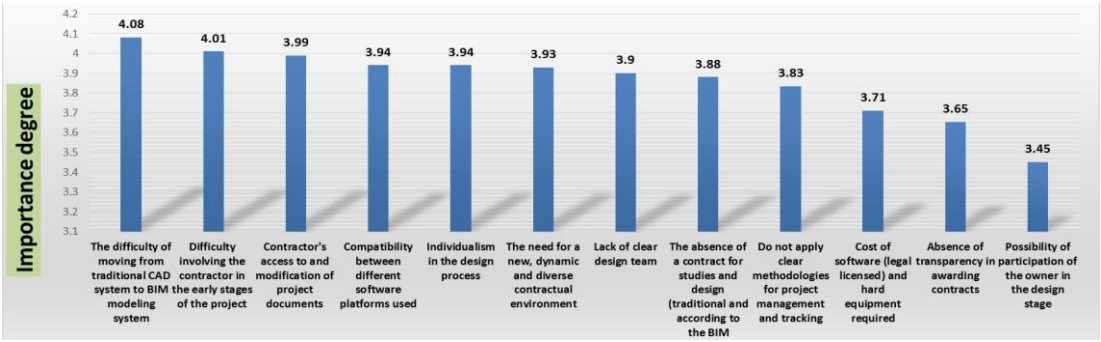

Figure 22: Obstacles to apply BIM in the Syrian Construction Industry (high importance)

engineering expertise in large and complex projects, The designed product is limited and defective - does not meet all the requirements of the owner or non-economic, and is free of defects and errors, which will lead to generate many change orders by all parties of the project, especially by the owner, during the execution phase and thus delay and increase in cost and the rise of disputes between the parties ... One of the most important factors here is the number (3) individual spirit/ behavior in the design process, (6) The absence of a special contract for studies and design (traditional and according to the BIM system) reflects the weakness of the system of engineering contracts in Syria. (1) The absence of a clear design team, also related to the former workers, noting the absence of a specific design team in the traditional system while the BIM system bases on collective teams (interactive collaboration). There is no doubt that this group of factors is important because it is related to the design and design that determines the cost of the project. The designer has the greatest impact on the design cost which is: (49-55) % of the project cost (Omar, H.S., 2015).

In the second group, the factors related to the BIM system have three factors out of (8) ie (37.5%), which indicates the importance of the factors of this group that accompany the application of the BIM system. Factor 13 introduces the difficulty of change: (4.08) this factor reflects the reality of the difficulty of changing and moving from the relatively low-cost work traditional system to the new; that requires training, experience, and fear of the unknown this is apart from the high-cost possibilities. Factor 14, "Compatibility between the various software platforms used" and factor 11, "The cost of software (licensed and required) and the necessary hard equipment" are interrelated because this is considered a significant obstacle due to the difference between the software used in this field and the lack of possibility the use of legally licensed software which is considered to be high cost compared to the income of the Syrian engineer or consulting office, especially at this stage.

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Within the third group (c): the administrative, financial and legal factors we have five important factors out of eight (5/8 = 62.5%). The most important of these are factors (18,19,21,23,24) . The involvement of the contractor in the early stages of the project - in accordance with the current , contracting system "," the contractor's access to and modification of project documentation during implementation "and" the need for a new dynamic and diversified contractual environment ". This is considered one of the main obstacles to the development of the Syrian construction industry. The amendment of the laws governing this sector is very difficult and takes place at very different intervals ... so that the development in the global construction industry, in particular, the design and contracting methods implementation, there is a great need for dynamic contracting systems that take into account the project conditions, size, complexity, and importance. "Lack of transparency in work / administrative and financial corruption associated with project contracts" and "failure to apply clear methodologies for project management and follow-up" are also linked to each other and contracting systems and the adoption of clear methodologies for project management, meanwhile the modern project management methodologies, including the BIM system, are integrated design, implementation and investment systems that reduce waste and financial and administrative corruption

Factors of medium importance

Within this level of classification, there are a number of factors that must be addressed as well. In Group A, the majority of these factors are (2,4,7,9), which relate to the need to determine the qualifications of the design project manager and the current design audit mechanism. The design system is clearly more effective in the BIM system as a result of teamwork and full coordination between the different design team. Errors are also discovered immediately before implementation. The effect of possible changes on the design is also known. Another important factor is the absence of a uniform system of cost among designers, especially since the BIM system uses a specific cost system to be implemented effectively. Within Group B and Group C we have three factors that hinder and delay the application of BIM in the Syrian construction industry, but should be noted that these factors are not limited to the BIM system, it prevent the obtaining of high performance indicators for the construction industry within the traditional system, but in the BIM system their effect will be greater, Figure (10).

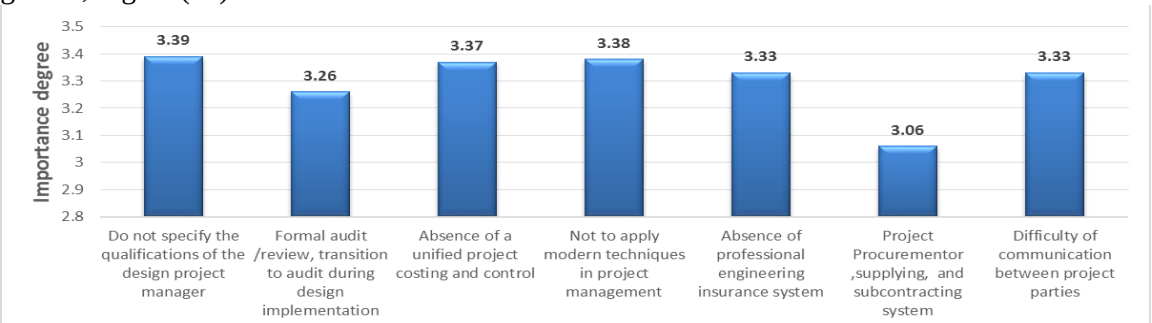

Figure 23: factors impeding the Application of BIM in the Syrian AEC Industry (Medium importance)

Therefore, the obstacles of applying the BIM system in AEC industry in Syrian can be summarized and ranked as shown in figure 11.

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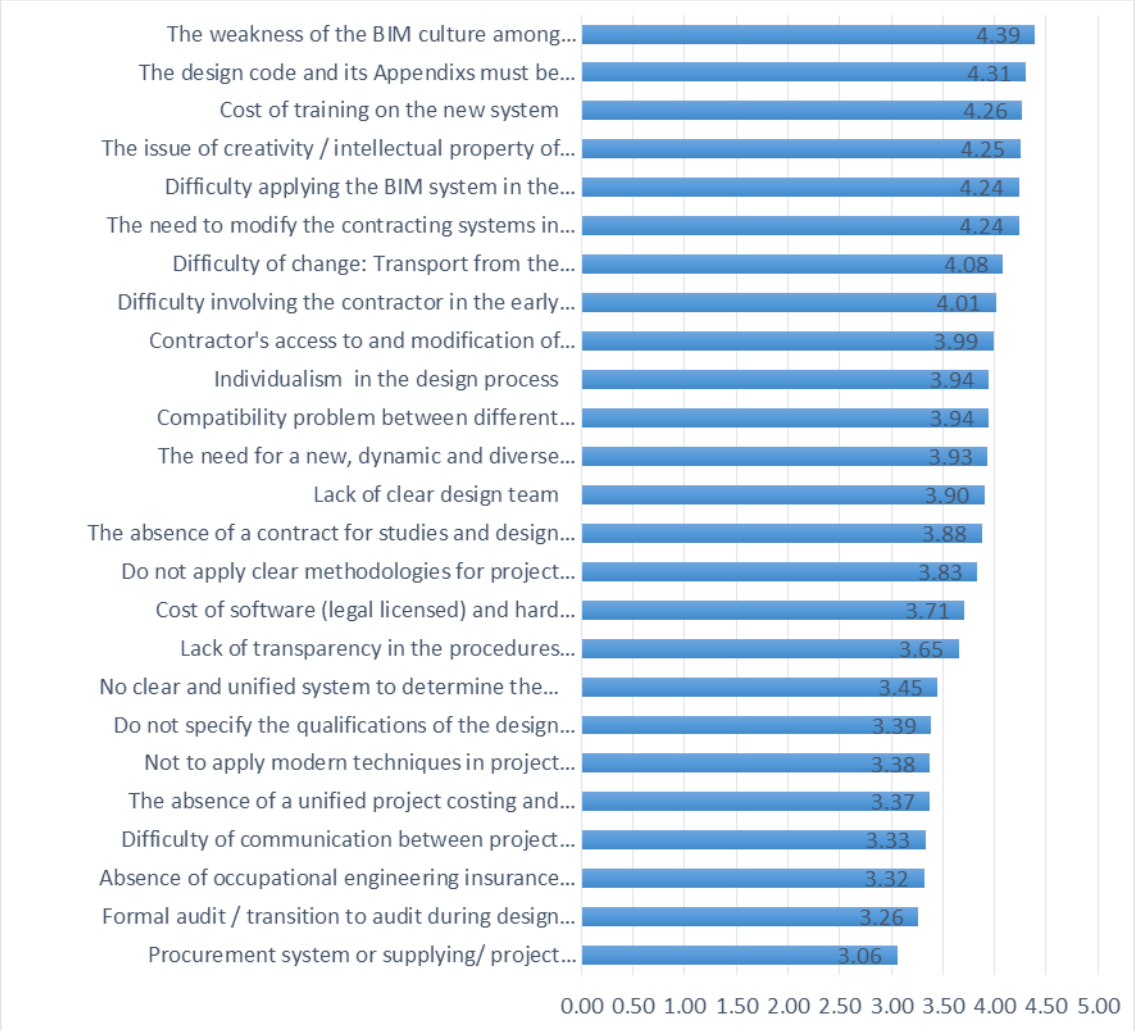
The weakness of the BIM culture among... 4.39
The design code and its Appendixs must be... 4.31
Cost of training on the new system 4.26
The issue of creativity / intellectual property of... 4.25
Difficulty applying the BIM system in the... 4.24
The need to modify the contracting systems in... 4.24
Difficulty of change: Transport from the... 4.08
Difficulty involving the contractor in the early... 4.01
Contractor's access to and modification of... 3.99
Individualism in the design process 3.94
Compatibility problem between different... 3.94
The need for a new, dynamic and diverse... 3.93
Lack of clear design team 3.90
The absence of a contract for studies and design... 3.88
Do not apply clear methodologies for project... 3.83
Cost of software (legal licensed) and hard... 3.71
Lack of transparency in the procedures... 3.65
No clear and unified system to determine the... 3.45
Do not specify the qualifications of the design... 3.39
Not to apply modern techniques in project... 3.38
The absence of a unified project costing and... 3.37
Difficulty of communication between project... 3.33
Absence of occupational engineering insurance... 3.32
Formal audit / transition to audit during design... 3.26
Procurement system or supplying/ project... 3.06
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00

Figure 24: Ranking of the Obstacles of applying the BIM system

Requirements for the implementation of the BIM system in Syria:

As a result of this research, and through the results of the questionnaire, and by studying the reality of the construction industry in Syria and compared with the applications of the BIM system in developed countries, we find that the successful application of the BIM system in Syria requires a fundamental change in the systems of the Syrian AEC industry. It is necessary to reconsider the entire system of the construction industry in all its aspects, specifically, the changes should be in the following aspects (Mia, R., et al. 2008, Breen, G., 2018):

A. **Legal and legislative requirements:**

1. Developing a contract for the design phase or engineering consultancy (design + supervision).
2. Modifying the Intellectual Property System for design ownership.
3. Improve the Syrian contract law so that the contractor can be involved in the design stage.
4. Enact laws that are binding or applicable at all stages of the project.

B. **Set of administrative and cultural factors**:

1. The need to spread the culture and benefits of BIM among those involved in projects or the AEC industry.
2. Encourage interactive collaboration within the project design team.
3. The need for large-scale training of cadres for this technique
4. Introduce this system in the curriculum of engineering colleges.
5. The need for a time frame plan for future application.
6. The importance of project participants recognizing the actual benefits of applying the BIM.

C. **Technical and financial factors**

1. Modification the Syrian concrete design with the BIM requirements.
2. Provide BIM software compatible with software developed locally in the field of design.
3. The need to invest in the engineering software industry and its applications in accordance with the BIM system.
4. Promote the widespread use of this technology to reduce the cost of acquiring its own software.

5. Conclusion

However, the traditional systems in the AEC industry deal with various phases of the project totally separation and absence of integration manner, BIM totally integrates the phases from the initial design to the maintenance and operation.

BIM and IPD are a significant qualitative development in the management of the AEC industry. The companies or departments that will adopt these systems in its engineering work are only eligible to compete later in the global market. Experts emphasize that the BIM system will be the main way to design, construct and manage projects, which is the way to reduce waste of resources. Therefore, this study aimed to find the obstacles and how it can be overcame to rapidly BIM implementation in Syria. An extensive investigation for previous studies and a structured questionnaire conducted to achieve this aim. This research finds that, BIM adaption need a cultural change in the construction industry as a whole to make sure that this will contribute to the growth and development of the AEC industry.

This study finds the top factors that impeding the BIM applying are: 1) The absence of BIM culture among AEC industry projects participants, 2) The need to develop a design code compatible with the BIM system, 3) Cost of training on the new system, 4) The issue of creativity and intellectual property, 5) Difficulty applying the BIM system in the executive stage due to the lack of qualified contractors, 6) The need to modify the contracting systems in accordance with the BIM, 7) The resistance of change: transfer from the traditional system to the BIM, 8) Difficulty involving the contractor in the early stages of the project, 9) Contractor's access to and modification of project documents during implementation, 10) Compatibility problem between different software platforms used, 11) Individualism in the design process, 12) The need for a new, dynamic and diverse contractual environment, 13) Lack of clear design team, 14) The absence of a contract for studies and design (traditional and according to the BIM system), 15) Do not apply clear methodologies for project management and tracking. The questionnaire respondents claim that there is a great opportunity to implement the BIM system in the reconstruction phase, especially in the design stage as a first step. The study recommends that the most important structural changes that should be made in the structure of the legislation governing the Syrian construction industry before starting to apply to maximize the benefit and achieve the highest return. In the current circumstances of the construction industry in Syria, it is very difficult to implement the entire system, but it can be implemented in

stages, such as the design stage, especially in the reconstruction phase, which requires great engineering effort and cooperation among all stakeholders, including civil society as an end user of the project. It is necessary that the Association of Engineers, Contractors, and ministries involved in the construction industry organize specialized workshops and training courses on this system and its implementation mechanism, in order to develop a framework plan for its implementation within a specified period of time.

In the future, we recommend that other issues related to the application of the BIM system in Syria should be considered, for example, the impact of the BIM system on reducing and settlement project disputes.

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Available online at: http://bimarabia.com/IJBES/

December- 2018; Volume: 1 Issue: 1 **ISSN 2571-1075**

At the end of this issue, we wish it is a good and a distinct start to the IJBES, I would like to thank all those who contributed to its achievement since the first idea until today 31-12-2018. Thanks to the BIMarabia Research Center, the publisher of the Journal. The International scientific board who led the review and follow-up and coordination over the whole year of effort to accomplish this work. Based on a sense of responsibility and passion for scientific research, we have provided every possible means to monitor research and scientific papers interested in the field of BIM, and its review followed up with the distinguished authors to reach the best scientific level. We promise you more valuable papers in the next issue. We also sincerely invite you to put forward your constructive views and suggestions for the development of the Journal. And a special invitation to contribute to the publication of your articles and research in the field of BIM and modern management and other areas covered by the Journal and mentioned at the beginning of the issue.